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A PALAEONTOLOGICAL INVESTIGATION OF THE TABUK FORMATION IN THE AL-QASSIM AREA, SAUDI ARABIA

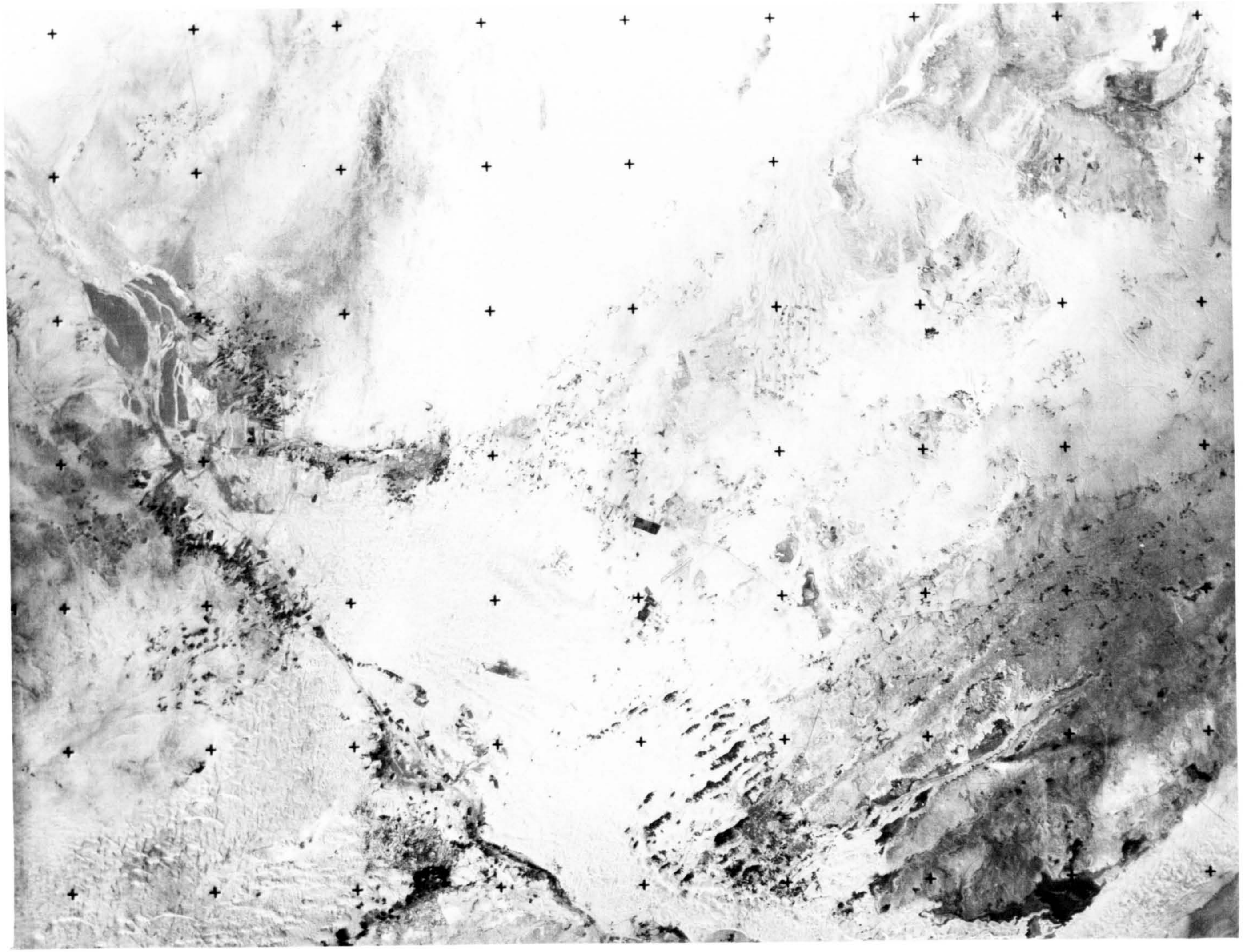
MOHAMMED H. MANDURAH

A dissertation in partial fulfillment of
the requirements of the degree of Ph.D. in
the University of Bristol

DECEMBER 1984

LANDSAT PHOTOGRAPH OF THE STUDY AREA

(The photograph shows the outcrops in Al-Qassim area, settlements, the new road and the vast area covered by sand dunes of the Al-Nafud desert. The new road which connects Al-Shuggah and Al-Bukayriah appears slightly eastward to the old road shown in Figure 6. North is oriented upwards.)



MEMORANDUM

This thesis is based on my personal field investigations in Al-Qassim, Saudi Arabia,on my independent palaentological preparations in the University of Bristol Geology Department, on advice and technical assistance which is fully acknowledged below and on items from existing published work which are referenced in detail within the text.

M H MANDURAH

M. H. Mandurah

Preface

This thesis presents new palaeontological information crucial to the geological understanding of certain sections of the Al-Qassim area. It adds to, and continues the discussion of previous works on the subject. This thesis is presented in the following form. Part I is an introduction to stratigraphy of the region in general, in particular the Lower Palaeozoic rocks and the Tabuk Formation in the light of existing literature. It provides the basis for discussion. Part II describes the principal geological sections chosen for study and gives their stratigraphical correlation to the type section. Part III records the sampling procedures as well as the preparation techniques utilised for different fossils. Part IV is the crux of the thesis. It is based on systematic palaeontology and describes taxa and their corresponding ages accordingly. Part V discusses the significance of the fossils studied and their relationship with other taxa worldwide. Part VI presents the conclusions of this study, regarding fauna, palynomorphs, environmental interpretation and regional palaeogeographic setting.

Acknowledgements

I would like to express my deepest thanks and gratitude to my supervisor, Prof. D. L. Dineley whose helpful advice and encouragement throughout the period of research both in Bristol and in the field has made this thesis possible, and also for reading and correcting the first draft of this thesis. I would also like especially to thank him for his kind support during a period of family afflictions.

I am indebted to Dr. K. C. Allen of the Botany Department at Bristol University for enlightening me on the subject of palynomorphs, and also to Dr. C. P. Hughes of Cambridge University and Prof. C. P. Downie at Sheffield University for their help and discussion regarding Ordovician trilobites and acritarchs respectively as well as to Prof. D. J. Shearman and Drs. J. Ferguson and R. G. Davis at Imperial College, London.

Particular mention must also be made of the invaluable assistance and support given by the academic and technical staff at the Geology Department of Bristol University, especially Dr. E. J. Loeffler who has been a constant source of useful discussion.

I am also grateful to King Abdul Aziz University, Jeddah, for their financial support during the period of study.

I would like to thank Dr. H. Bahafzalla, Br. M. Shohayeb and Br. T. Taib as well as those others whom for forgetfulness I could not mention by name.

Finally, thanks to all my family for their loyalty and support, particularly to my wife Umm Belal for being so understanding and patient, and for providing continuous comfort and encouragement.

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Abstract

In an assessment of rocks previously mapped as Tabuk Formation, the stratigraphical succession of the selected sections in Al-Qassim area is built up according to the age indicated by the graptolites the strata contain. Twelve graptolite species (of the genera Didymograptus, Glyptograptus, Climacograptus, Monograptus and Petalograptus) of the early, Upper Ordovician and early Silurian have been observed and studied. Three trilobite genera (Neseuretus, Hanchungolithus, and Plaesiacomia), based on Ordovician species, as well as two genera (Platycoryphe, and Calymene) of the Silurian are described. The Ordovician trilobites may be regarded as a cold water fauna and this is in conformity with the non-carbonate character of the lithologies of the enclosing sediments. The age given to the twenty two Silurian palynomorphs (spores and acritarchs) identified here is confirmed by associated Silurian graptolites. Thus the ages of the rocks in Al-Qassim area that might have been correlated to the Devonian part of the Tabuk Formation are older than Devonian.

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I

INTRODUCTION

a. Nature of the study in this thesis

This thesis presents the results of a careful examination of sections in rocks previously ascribed to the Tabuk formation, but which were poorly known biostratigraphically. Their age was uncertain, possibly Lower Devonian to judge from existing maps of the region. In the event this age has not been confirmed and a general account of the Lower Palaeozoic strata of central Saudi Arabia is given below as a background to what follows. The fossils from the sections described allow a reassessment of the local biostratigraphy and an interpretation of the environments of deposition. The relationship of the faunas and their habitats to contemporary communities and environments is also discussed.

b. Phanerozoic cover of the Arabian Shield and a general statement about the present state of knowledge of stratigraphy/biostratigraphy.

The geology of Saudi Arabia in general has been divided between two main rock types. A Precambrian complex of igneous and metamorphic rocks, forming the Arabian shield, extends from the north-west to the south-west being enlarged (at mid-outcrop) to form an easterly bulging arc. It separated from the African continent in early Tertiary times (Brown and Jackson, 1979) by the opening of the Red Sea rift. The remaining assembly is the sedimentary rocks of continental and shallow-water shelf origin which was deposited between Cambrian and Pliocene times (Powers, 1968), dipping gently north-east, east, and south-east from less than 0.30° to slightly more 1.00°. These sediments cover nearly two thirds of the 2,150,000 km² area of Saudi Arabia. They crop out in a great curved belt surrounding the eastern margin of the Arabian shield. The sedimentary section exposed above the Precambrian is divided naturally according to lithological characters and separated by unconformities into eight major divisions (Powers et al. 1966) see Table 1.

These eight major stratigraphic divisions have been recognized also in subsurface sections (Powers, 1968). They are:-

1. Lower Palaeozoic clastic rocks - Cambrian to Lower Devonian; dominantly coarse clastics but with some thin carbonate beds in the uppermost part.

2. Upper Permian to Upper Triassic dominantly clastic rocks, alternating non marine-marine units, with thick calcareous intervals at the base and in the middle.
3. Lower and Middle Jurassic clastic and carbonate rocks; Toarcian to Callovian in central Arabia marine shale interbeded with carbonates, which grade to sandstone in northern and southern areas of outcrop.
4. Upper Jurassic and early Lower Cretaceous rocks- Callovian through Valanginian; mostly carbonate but with alternating evaporite-normal marine cycles near the top of the Jurassic.
5. Late Lower Cretaceous clastic rocks, Hauterivian through Aptian; dominantly coarse clastics with a thin basal carbonate unit.
6. Middle Cretaceous clastic rocks.Cenomanian to Turonian (?); dominantly coarse clastic rocks.
7. Upper Cretaceous to Eocene carbonate rocks Campanian through Lutetian; carbonate units but in subsurface lower Eocene includes evaporite section.
8. Miocene and Pliocene clastic rocks dominantly sandy limestone and sandstone.

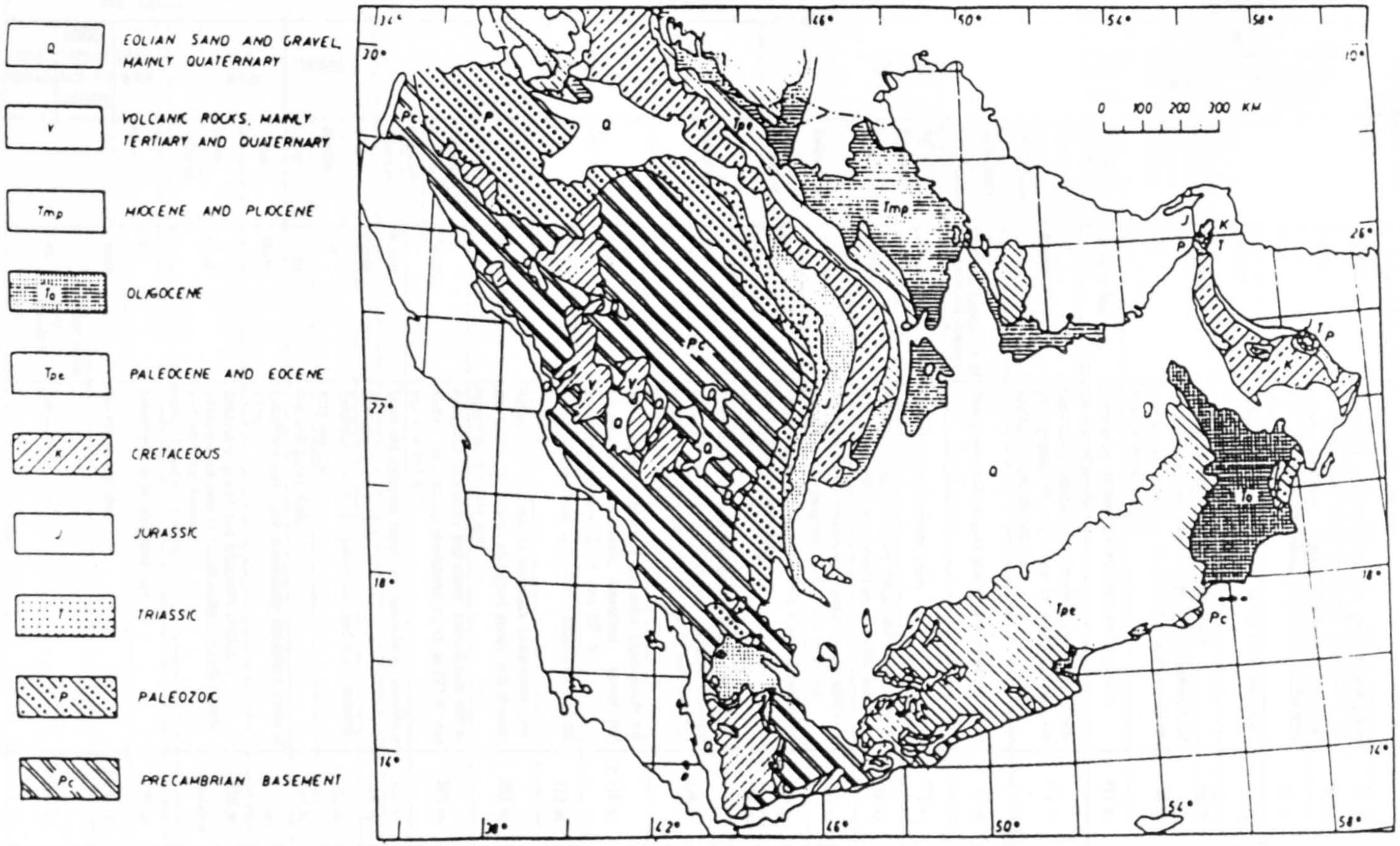


FIG. 1 GENERALISED GEOLOGIC MAP OF THE ARABIAN PENINSULA

Age				Formation	Generalized lithologic description	Thickness (Type or reference section)	Major stratigraphic divisions
CENOZOIC	QUATERNARY AND TERTIARY			Surficial deposits	Gravel, sand and silt		
CENOZOIC	TERTIARY	Miocene and Pliocene		Kharj	Limestone lacustrine limestone, gypsum, and gravel	28 m	Miocene and Pliocene Clastic Rocks
CENOZOIC	TERTIARY	Miocene and Pliocene		Hofuf	Sandy marl and sandy limestone, subordinate calcareous sandstone Local gravel beds in lower part	95 m	Miocene and Pliocene Clastic Rocks
CENOZOIC	TERTIARY	Miocene and Pliocene		Dam	Marl and shale, subordinate sandstone, chalky limestone, and coquina	91 m	Miocene and Pliocene Clastic Rocks
CENOZOIC	TERTIARY	Miocene and Pliocene		Hadrukh	Calcareous, silty sandstone, sandy limestone; local chert	84 m	Miocene and Pliocene Clastic Rocks
CENOZOIC	TERTIARY	Eocene	Lutetian	Dammam	Limestone, dolomite, marl, and shale	33 m	Upper Cretaceous to Eocene Carbonate Rocks
CENOZOIC	TERTIARY	Eocene	Ypresian	Rus	Marl, chalky limestone, and gypsum; common chert and geodal quartz in lower part. Dominantly anhydrite in subsurface	56 m	Upper Cretaceous to Eocene Carbonate Rocks
CENOZOIC	TERTIARY	Paleocene	Thanetian Montian(?)	Umm er Radhuma	Limestone, dolomitic limestone, and dolomite	243 m	Upper Cretaceous to Eocene Carbonate Rocks
				Possible disconformity			
MESOZOIC	CRETACEOUS		Maestrichtian Campanian	Aruma	Limestone, subordinate dolomite and shale. Lower part grades to sandstone in northwestern and southern areas of outcrop	142 m	Upper Cretaceous to Eocene Carbonate Rocks
MESOZOIC	CRETACEOUS		Turonian(?) Cenomanian	Wasia (Sakaka Sandstone of northwest Arabia)	Sandstone, subordinate shale, rare dolomite lenses	42 m	Middle Cretaceous Clastic Rocks
MESOZOIC	CRETACEOUS		Aptian Barremian	Biyadh	Sandstone, subordinate shale	425 m	Late Lower Cretaceous Clastic Rocks
MESOZOIC	CRETACEOUS		Hauterivian	Buwaib	Biogenic calcarenite and calcarenitic limestone interbedded with fine sandstone in upper part	18 m	Late Lower Cretaceous Clastic Rocks
MESOZOIC	CRETACEOUS		Valanginian	Yamama	Biogenic-pellet calcarenite; subordinate aphanitic limestone and biogenic calcarenitic limestone	46 m	Upper Jurassic and early Lower Cretaceous Carbonate Rocks
MESOZOIC	CRETACEOUS		Berriasian	Sulaiy	Chalky aphanitic limestone; rare biogenic calcarenite and calcarenite limestone	170 m	Upper Jurassic and early Lower Cretaceous Carbonate Rocks
MESOZOIC	JURASSIC		Tithonian	Hith	Anhydrite	90 m	Upper Jurassic and early Lower Cretaceous Carbonate Rocks
MESOZOIC	JURASSIC		Tithonian	Arab	Calcarenite, calcarenitic and aphanitic limestone, dolomite and some anhydrite. Solution-collapse carbonate breccia on outcrop due to loss of interbedded anhydrite	124 m	Upper Jurassic and early Lower Cretaceous Carbonate Rocks
MESOZOIC	JURASSIC		Kimmeridgian	Jubaila	Aphanitic limestone and dolomite; subordinate calcarenite and calcarenitic limestone. Lower part sandstone between 20° N. and 22° N.	±118 m	Upper Jurassic and early Lower Cretaceous Carbonate Rocks
MESOZOIC	JURASSIC		Kimmeridgian	Hanifa	Aphanitic limestone, calcarenitic limestone, and calcarenite	113 m	Upper Jurassic and early Lower Cretaceous Carbonate Rocks
MESOZOIC	JURASSIC		Oxfordian Callovian	Tuwaiq Mountain	Aphanitic limestone; subordinate calcarenitic limestone and calcarenite. Abundant corals and stromatoporoids in upper part	203 m	Upper Jurassic and early Lower Cretaceous Carbonate Rocks
MESOZOIC	JURASSIC		Callovian(?) Bathonian Bajocian	Dhruma	Aphanitic limestone and shale; subordinate calcarenite Dominantly sandstone south of 22° N. and north of 26° N.	375 m	Lower and Middle Jurassic Clastic and Carbonate Rocks
MESOZOIC	JURASSIC		Toarcian	Marrat	Shale and aphanitic limestone; subordinate sandstone	103 m	Lower and Middle Jurassic Clastic and Carbonate Rocks
MESOZOIC	TRIASSIC		Upper	Minjur	Sandstone; some shale	315 m	Permian and Triassic Clastic Rocks
MESOZOIC	TRIASSIC		Middle	Jilh	Sandstone, aphanitic limestone, and shale; subordinate gypsum	±326 m	Permian and Triassic Clastic Rocks
MESOZOIC	TRIASSIC		Lower	Sudair	Red and green shale	116 m	Permian and Triassic Clastic Rocks
PALEOZOIC	PERMIAN		Upper	Khuff	Limestone and shale; dominantly sandstone south of 21°N	171 m	Permian and Triassic Clastic Rocks
PALEOZOIC	PERMIAN		Lower undated	Wajid	Sandstone, gravel, and basement erratics (Recognized only in southwestern Saudi Arabia and northern Yemen)	950 m calculated	Lower Paleozoic Clastic Rocks
				Precambrian basement complex			
PALEOZOIC	DEVONIAN		Lower	Jauf	Limestone, shale, and sandstone	299 m	Lower Paleozoic Clastic Rocks
PALEOZOIC	ORDOVICIAN AND SILURIAN			Tabuk	Sandstone and shale	1,072 m	Lower Paleozoic Clastic Rocks
PALEOZOIC	CAMBRIAN			Saq: Umm Sahm, Ram, Quweira, Siq	Sandstone	+ 600 m	Lower Paleozoic Clastic Rocks
				Precambrian basement complex			

TABLE 1 SAUDI ARABIAN OUTCROP SEQUENCE
(from Powers et al 1966)

c. Lower Palaeozoic rocks of Saudi Arabia

Cambrian:-

The Cambrian sequence in Saudi Arabia is exposed in the north-west, and becomes widely distributed along the eastern margin of crystalline core of the Arabian shield. The thickness of these Cambrian rocks is a few hundred metres in the Arabian Shelf region. It has been stable tectonically and is only slightly tilted eastwards. It is mainly characterized by relatively thin deposits resting unconformably on pre-Cambrian metamorphic and igneous rocks and conformably overlain by Ordovician rocks. In north-western Saudi Arabia Powers et al. (1966) described the basement surface of the Cambrian as a flat peneplain, transgressed by the basal conglomerates of the Saq sandstone. The base dips regularly north-east under the sedimentary cover with a dip of approximately 1.5°. The basal conglomerates consist of dominantly angular rock fragments varying in size, and locally well cemented. In north-western Saudi Arabia the sandstone sequence of the Saq formation with thin basal conglomerates (Powers et al., 1966; Thralls and Hasson, 1956; Steineke et al., 1958) were considered as being of both Cambrian and Ordovician age, Helal (1964, 1965) however, restricted the term Saq Formation to Cambrian beds only, these underlying the early Ordovician Cruziana Series. The lithology of the Saq formation in general is uniform vertically as well as laterally. The governing rock type is a buff to grey and white sandstone, sorting varies from poorly to well-sorted quartz sandstone, commonly either friable or cemented to black ferruginous quartzite and cross-bedded.

In places, some interbeds of hard, silty rocks occur as well as pebbly beds (Powerset al, 1966). The thickness of the Saq formation is more than 600 m at the type section near 26°27' northern latitude. The thickness of the Saq according to Helal (1964) rises to about 400 m in the Hisma and Tabuk area. No fossils have been found in the Saq, but one may assume that these rocks are Cambrian in age because they rest unconformably on the Precambrian crystalline basement and are followed conformably by fossiliferous Lower Ordovician beds.

Ordovician:-

The Ordovician rocks of Saudi Arabia combine the deposits of two formations. Powers and others (1966, 1968) considered the upper part of the Saq Formation (Umm-Sahm Ram) and four members of the Tabuk formation as Ordovician in age. Helal (1965) thought the Cruziana Series equivalent to (Umm-Sahm Ram) and the Tabuk formation as a whole equivalent to the four members of the Tabuk formation as defined by Powers et al., (1966). The outcrop of the Ordovician rocks extends from north-west Saudi Arabia along the eastern margin of the crystalline Arabian shield. They mainly adjoin the Cambrian outcrops to the east, dipping towards the east and north-east with a dip between 1° and 5°. In Saudi Arabia the Ordovician sequences are estimated at 400 m. They have been described as units of purple, olive-green and grey graptolitic shale alternating with massive beds of reddish-brown to grey in part, cross-bedded and commonly micaceous sandstone (Powers and et al.,1966). The thicknesses of the Ordovician sequences are usually less than those of the local Cambrian rocks. On the Arabian shelf the Ordovician outcrops are virtually undisturbed and are only slightly tilted towards the east or north-east. These areas had in Lower Paleozoic times stable shelf conditions with uniform geological development. Therefore they are similar to the Cambrian; structure and sedimentation were mostly effected by the Pre-Cambrian basement trends in three main directions (N.W.-S.E.,N.E.-S.W.,N.-S.). In north-western Saudi Arabia the sequences of the Ordovician extend from the Jordan border to the south-east until they disappear beneath Silurian rocks and the sand of the Great Nafud. West of Hail south-eastwards they are gradually overlapped by Permian beds and wedge out completely near L. 24°.20'N.

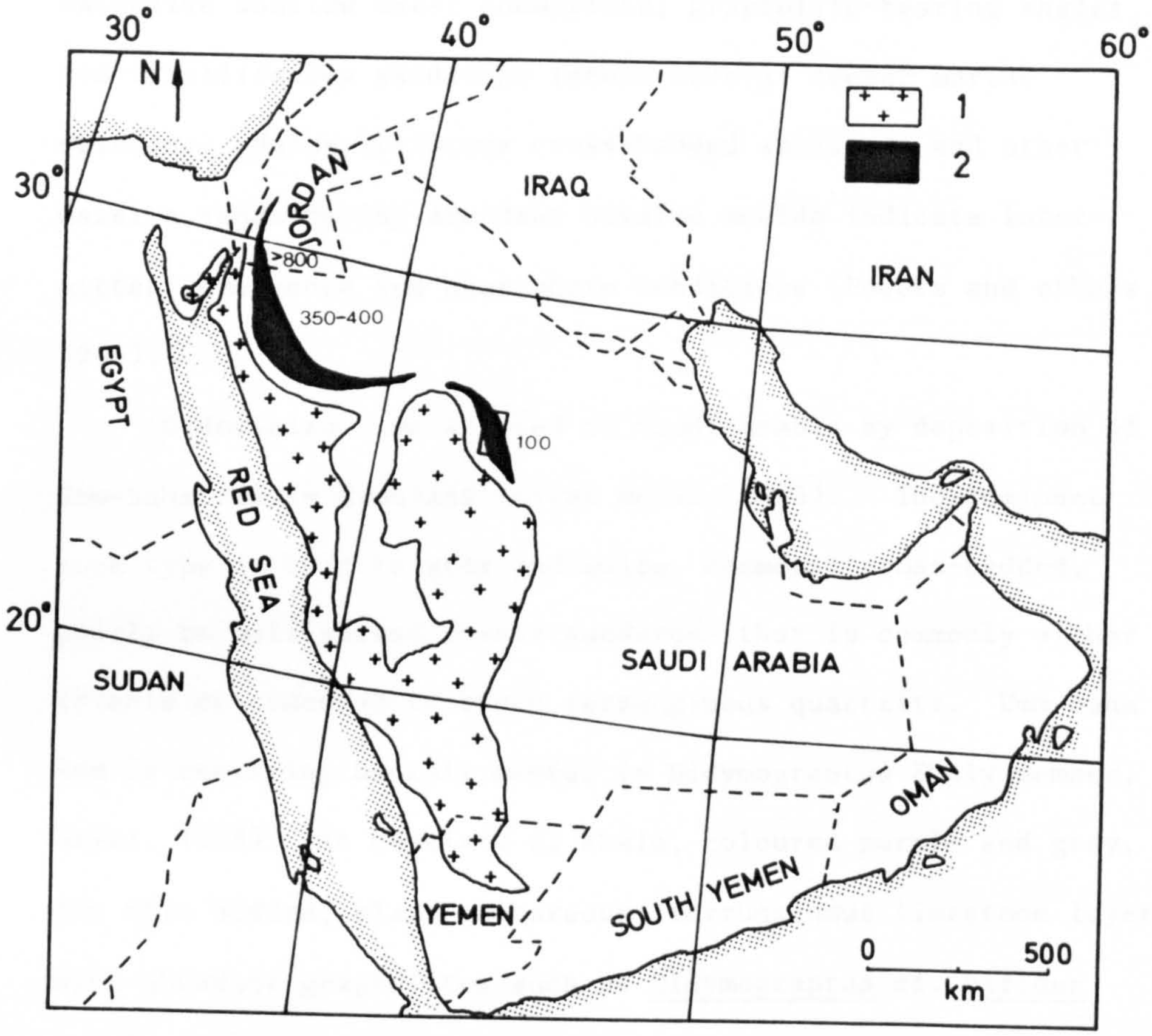


FIG. 2 LOCATION OF ORDOVICIAN OUTCROPS AT SURFACE IN SAUDI ARABIA

1 – Pre Cambrian at surface 2 – Ordovician at surface

(after R. Wolfart 1981)

(Powers et al., 1966). The Ordovician sequences extend without significant lithologic change into southern Jordan. The lithological characters of the Ordovician rocks reflect extensive shallow water conditions, graptolite-bearing shales and fossiliferous sandstone record several deeper marine episodes. Unfossiliferous cross-bedded sandstone and other massive sands having abundant bivalve moulds indicate intermittent emergence and near shore conditions (Powers and others, 1966).

Ordovician time started in Saudi Arabia by deposition of the Umm-Sahm Ram (= Cruziana Series Helal, 1965). The dominant rock type is buff to grey and white, commonly cross-bedded, poorly to well-sorted quartz sandstone that is commonly either friable or cemented to black ferrunginous quartzite. Umm-Sahm Ram is overlying Hanadir member (= Didymograptus Shaly member, Helal, 1965). It consists of shale, coloured purple and grey, and a few thin bedded, platy calcareous, ferrunginous limestone layers with abundant graptolites such as Didymograptus cf. bifidus (Hall) D. protobifidus Elles. The trilobite tracks were referred by P. E. Cloud to Cruziana cf. furcifera d'Orbigny and C. huberi (Meunier) of early Ordovician age (about Arenig) (Powers et al., 1966). Helal assigned to his Cruziana Series Tremadoc to Arenig ages. Umm-Sahm Ram is conformably overlain by the Tabuk formation (Hanadir member. Powers and others, 1966), (= Didymograptus Shaly Member. Helal, 1964, 1965).

Umm-Sahm Ram is distinguished from the overlying Tabuk Formation because of the sharp contact between the graptolite bearing shale of the Tabuk and coarse grained cross-bedded sand-

stone of the Cruziana. In north-western Saudi Arabia this member is developed as a significant sequence of fossiliferous marine rocks. Upwards the sandstone is grey to brown and black and commonly cross-bedded. Helal (1964, 1965) has named this part of the sequence the lower Tabuk Sandy Member. No diagnostic fossils have been collected from the lower Tabuk Sandy Member except Sabellarifex. The third member of the Tabuk Formation (= Diplograptus Shaly Member) is of sandstone, siltstone and shaly varying in colour green, purple and grey complex, interbedded and following directly on the sandstone with Scolithus (=Lower Tabuk Sandy Member Helal). R.F. Ross (in Powers, 1968) has identified the graptolites as Climacograptus sp., Cl. cf. brevis, Orthograptus off. O. calcaratus periscus, Glyptograptus, Diplograptus sp. The Ordovician rock sequence ends probably with the fourth member of the Tabuk Formation and consists of sandstone, brown, micaceous, with abundant thin interbeds of olive-green shale and siltstone (= upper Tabuk Sandy Member, Helal 1964, 1968) of Ashgill age.

<table>
<tr><th colspan="2">Graptolite Zones of the British Isles
Williams et al. 1972</th><th colspan="2">North-western Saudi Arabia
Powers et al., 1966
Powers, 1968</th><th colspan="2">Saudi Arabia Tabuk area
Helal 1964, 1965</th></tr>
<tr><td colspan="2"></td><td colspan="2" rowspan="2"></td><td colspan="2">Tawil Mb.</td><td colspan="2" rowspan="2">Jauf Formation</td></tr>
<tr><td colspan="2">Silurian</td><td colspan="2">Member 6</td></tr>
<tr><td colspan="2" rowspan="2">Silurian</td><td rowspan="2"></td><td rowspan="2">Tabuk Formation</td><td colspan="2" rowspan="2">Members 4 - 5 sandstone, shale</td><td colspan="2">Tawil</td></tr>
<tr><td colspan="2">Sharawra</td></tr>
<tr><td rowspan="8">Ordovician</td><td rowspan="2">Ashgill</td><td>D. anceps
D. complanatus</td><td rowspan="6"></td><td colspan="2" rowspan="2"></td><td>Upper Tabuk Sandy Members</td><td rowspan="6">Tabuk Formation</td></tr>
<tr><td rowspan="4">Caradoc</td><td>P. linearis
D. clingani
C. wilsoni
C. peltifer</td></tr>
<tr><td colspan="2">sandstone, shale with graptolites (3)</td><td>Diplograptus Shaly Member</td></tr>
<tr><td rowspan="2">Llandeilo</td><td>N. gracilis</td><td colspan="2" rowspan="2">sandstone with Scolithus (2)</td><td rowspan="2">Lower Tabuk Sandy Member</td></tr>
<tr><td>G. teretiusculus</td></tr>
<tr><td rowspan="2">Llanvirn</td><td>D. murchisoni</td><td colspan="2" rowspan="2">Hanadir Member (1)</td><td rowspan="2">Didymograptus Shaly Member</td></tr>
<tr><td>D. bifidus</td></tr>
<tr><td rowspan="2">Arenig</td><td>D. hirundo
D. extensus</td><td rowspan="2">Umm Sahm Ram</td><td rowspan="3">Saq</td><td rowspan="3">Cruziana Series</td></tr>
<tr><td rowspan="2">Tremadoc</td><td>C. tenellus
D. flabelliforme*</td></tr>
<tr><td colspan="2">Cambrian</td><td></td><td>Quweira</td><td>Saq</td></tr>
</table>

Fig. 3. Stratigraphical correlation of the Ordovician rocks of Saudi Arabia (After Wolfart, 1981).

*Now Rhabdinopora flabelliformis. See Erdtmann in Bassett, M.G. and Dean, W.T. The Cambrian Ordovician Boundary.

Silurian:-

Silurian deposits occur in north-eastern Saudi Arabia along the eastern margin of the Arabian shield and east of the Cambro-Ordovician rocks. It is a series composed of clastic deposits, and like the other Lower Palaeozoic series is a minor part of the huge blanket of sedimentary rocks which cover the north-eastern slope of the Arabian craton. Usually the landscape here is of an arid inselberge type. The Silurian rocks cover the Tabuk area west of the Great Nafud. The wide Tabuk exposure of Silurian forms a broad planar surface, in places broken by north-west, south-east structural ridges and drainage channels (Powers et al., 1966). Differential relief averages about 50 m., individual hills rising higher above the general ground level. The pre-Tawil (Sharawra) is differentiated from Saq below and Tawil Member above by alternating hard and soft clastic rocks which weather to a relatively smooth surface, while the others give a rough hummocky surface formed by strongly crossbedded sandstone. The outcrops of the Silurian extend in Saudi Arabia from about 29° N to 25°-26° N, there wedging out completely, as do the Ordovician rocks. The Silurian sequences consist of sandstone and shaly rocks overlaying the Cambro-Ordovician sandstone. The Silurian rocks have been ascribed to members 4 and 5 of the Tabuk formation and the Tawil considered as a member of that formation (Powers et al., 1966; and Powers, 1968). Helal (1964, 1965) divided the Silurian rocks into Sharawra and Tawil Formations and also divided the Sharawra Formation into two members. At the base of the formation is the Climacograptus-Orthoceratid Member, and the Sharawra Sandy Member at the top. The Climacograptus-

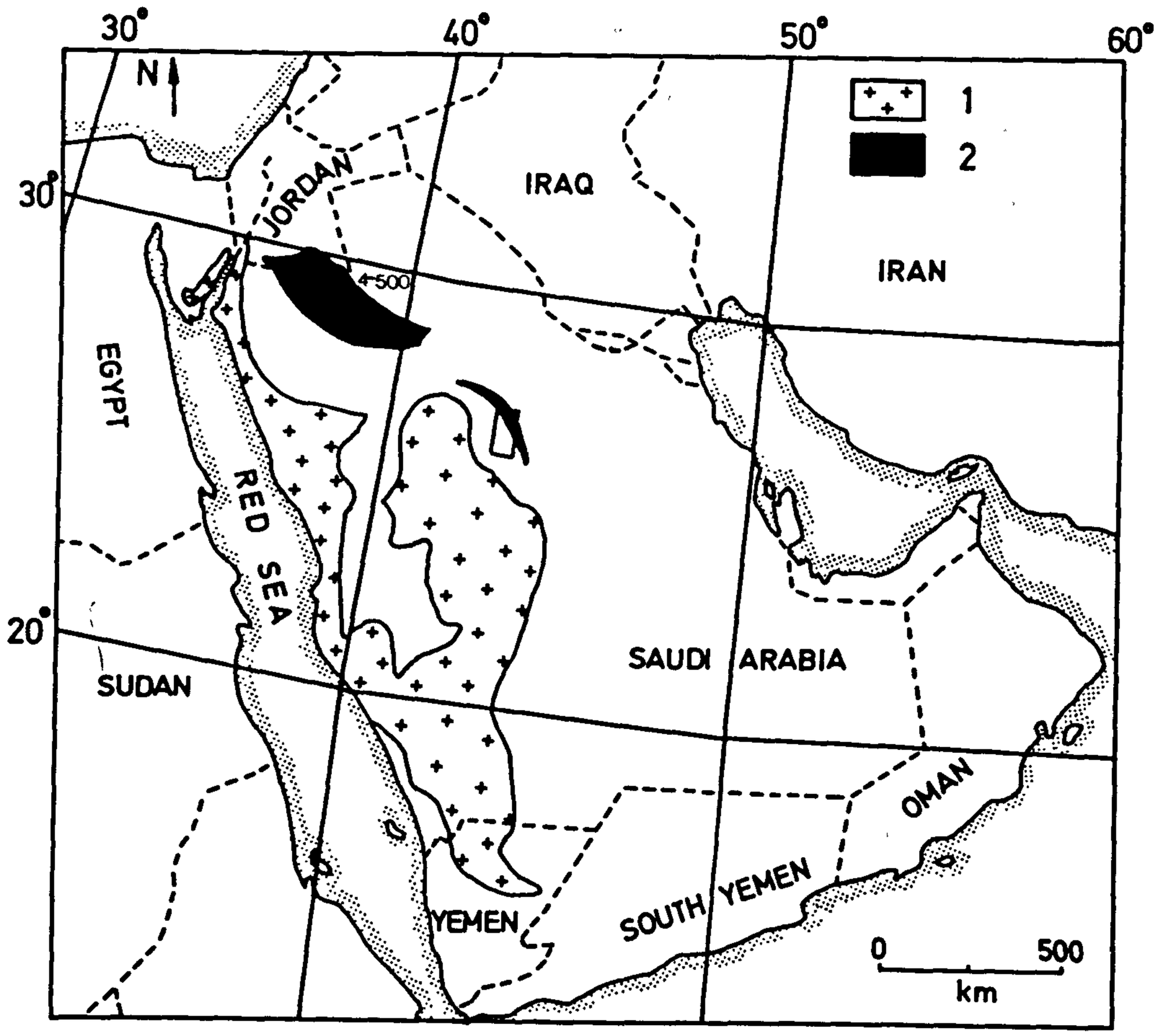


FIG. 4 LOCATION OF SILURIAN OUTCROPS AT SURFACE IN SAUDI ARABIA

1—Pre Cambrian at surface 2—Silurian at surface

(after R.Wolfart 1981)

Orthoceratid Member consists of coloured sands and siltstones with sand intercalations and overlies unconformably the Ordovician upper Tabuk Sandy Member. The Climacograptus-Orthoceratid Member is about 135 m in thickness and rich with fossils. According to Thralls and others (1956) the Climacograptus-bearing shales are lower most Silurian in age. Powers et al.(1966) and Powers (1968) measured Member 4 as 104.9 m thick - it consists of sandstone, brown and micaceous with abundant thin interbeds of olive-green shale and siltstone. The Monograptus and Rastrites-bearing shales were collected in the Qusayba escarpment (Powers, 1966), considered by Berry and Boucot (1972) to be approximately middle Llandovery in age. It may be that the Climacograptus-Orthoceratid Member,Helal (1965) is the same as the Rastrites beds of Qusayba, Powers (1968). Overlaying the Climacograptus Member is the Sharawra Sandy Member approximately 320 m thick forming the main body of the Sharawra plateau. It mainly consists of pastel-shaded, pink, green, and grey, fine-to coarse-grained sandstone showing wool-sack structures in the upper part and intercalations of red and greyish green shales. Its upper boundary is everywhere marked by iron oxide concentrations at the sharp and unconformable contact with the Tawil Formation. Marine fossils are found only in the upper portions of the member. These are mainly bivalves and gastropods, representing the dominant part of the fauna which inhabited a shallow littoral environment. Tabular moulds, worm trails, and arthropod tracks were also noticed within the Sharawra Sandy Member. Helal considered the member as Silurian in age because of the occurrence of lower Silurian rocks below it. Tawil Formation follows the Sharawra Sandy

Member Helal (1964, 1965). According to Helal the Tawil Formation is chiefly distinguished by its purplish red to black colour and by haematite-coated quartz pebbles and grains at some levels. At the type locality the Tawil Formation consists of brown sandstone and minor amounts of siltstone and shale, in all 180 m thick. The sandstones at the base and the top of the Tawil Formation are a distinctive feature; Helal considered them as an indication of the change from transgressive to regressive conditions. The base of the Tawil is marked unconformably by pastel, light-coloured, thin-bedded sandstone of the uppermost Sharawra and by massive-bedded sandstone with iron oxide concentrations and massive quartz pebble beds of the basal Tawil. Within the Tabuk area, the Tawil Formation is unconformably overlain by marly limestone of upper Cretaceous and/or lower Eocene age. In the Jauf area however the Devonian Jauf Formation overlays the Tawil Formation. The contact shows a marked unconformity. No diagnostic fossils were found in the Tawil Formation, except worm trails and arthropod tracks (Cruziana). Powers et al. (1966), Powers (1968) considered the Tawil as members of Tabuk Formation and Devonian in age.

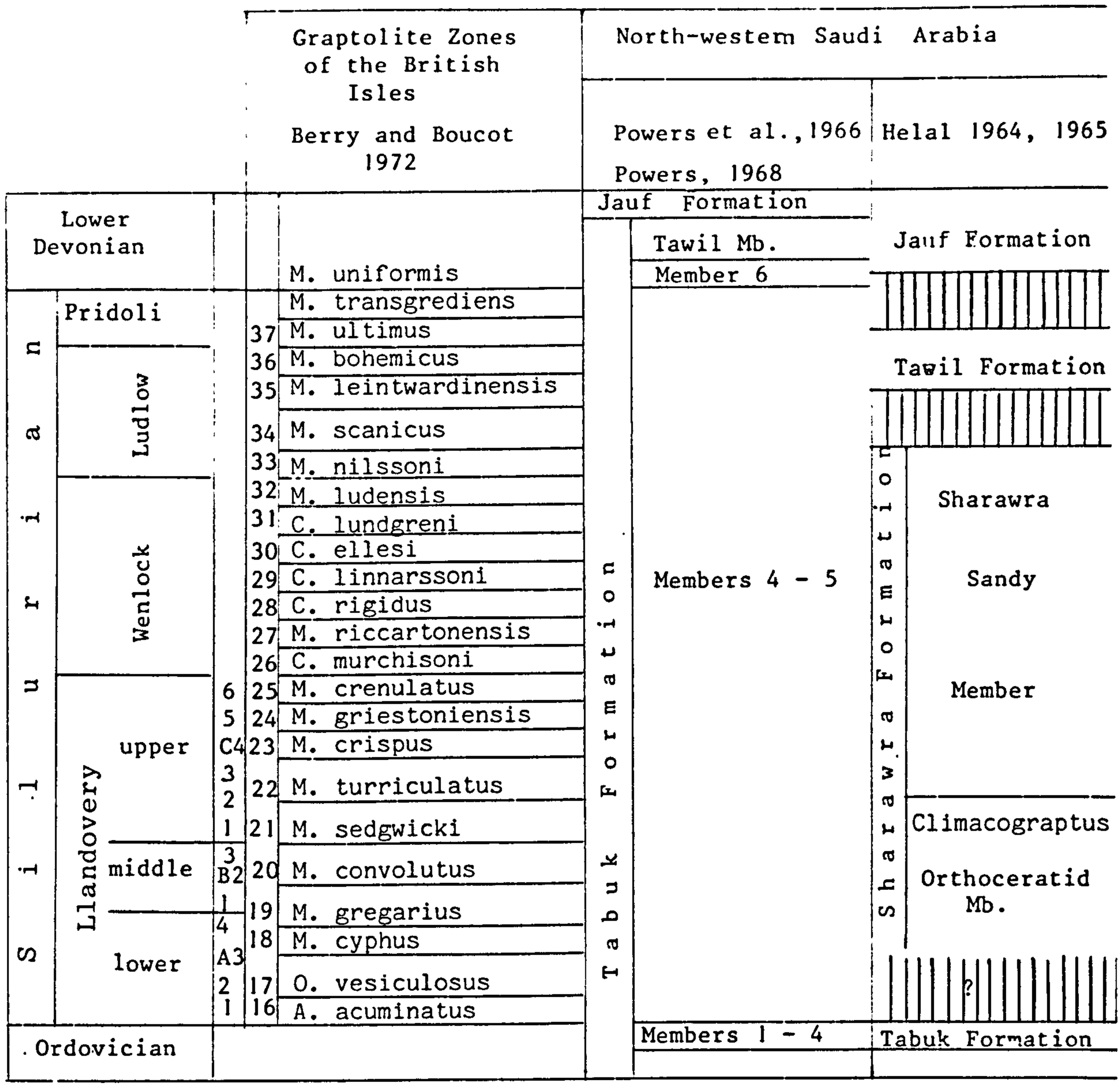


Fig. 5 Stratigraphical correlation of the Silurian rocks of Saudi Arabia (After Wolfart, 1981).

d. The Tabuk Formation

The name of the formation has been derived from an area in north-west Saudi Arabia (R.A. Bramkamp, 1954). The Tabuk Formation previously included all beds between the Saq Sandstone Formation and coarse-crossbedded sandstone of the Tawil Formation (Steineke et al., 1958). A later definition proposed by Powers et al. (1966) included the Tawil Formation within the Tabuk Formation and the Tawil was considered as a member of that formation. The Tabuk in the Al Qassim region is disconformably overlain by the later rocks. The Tabuk Formation is exposed in four main areas separated from each other by the Gread Nefud sand belt. The type sequence of the formation consists of several sections and the total thickness is about 1071.5 m with few metres that have not been measured (Powers et al., 1966). The contact between the base of the Tabuk and the underlying Saq Sandstone Formation is sharp and apparently conformable between Didymograptus-bearing shale and coarse-grained cross-bedded sandstone (Powers et al., 1966). According to Davis et al. (1981), the change from one formation to the other is abrupt and non-transitional. At various localities [along At Tiniyat (27°41'N, 42°22'E) and 8 Km WSW of Al Kuhayfiyah (27°15'N, 42°55'E)] the base of the Tabuk Formation rests on a surface which truncates the forests and backslopes of the current-bedding in the sandstones of the under-laying Saq Formation. The surface must therefore be erosional. The top of the formation is a conformable contact between massive sandstone of the Tawil Member and shale and limestone of the Jauf

Formation (Powers and others, 1966).

The first of the four main areas in which the Tabuk Formation is exposed extends between Baqa and Burayadh, a distance of 280 Km south-east of Nefud and which provides sporadic exposures. The Tabuk Formation in this area supports a complex topography. Alluvium deposits cover much of the formation. Duricrust and gravel have been deposited during the Tertiary and effectively control the topographic form of this area. The measured thicknesses,obtained from two sections, each consist of several measured increments. The thickness at Baqa 27°N latitude is about 700 m (Powers and others, 1966). South of 27°N latitude much has been removed by pre-Khuff erosion. In the vicinity of Burayadah the formation is hidden by sand dunes of the Nefud. The Tabuk Formation is exposed in the second area from the western edge of the Great Nefud to the southern boundary, an outcrop 340 Km long and 240 Km wide. The most comprehensive exposure of the Tabuk has been found in this area with thickness of 1100 m, measured from two isolated sections (Powers and others, 1966). This area is further complicated because of faulting. The Tawil Sandstone Member outcrops in a wide band along the north-eastern margin of that area, and the contact between the Tawil and pre-Tawil beds is obvious along the southern edge of the AlHufrah plain. In this area the Tabuk exposure west of the Great Nefud forms a broad planar surface, in places intersected by north west-trending structural ridges and drainage channels. Differential relief averages about 50 m, individual hills rising somewhat higher above the general ground level (Powers and others, 1966). The pre-Tawil, alternating hard and soft clastic rocks, weather

to a relatively uniform surface, while the Saq Formation and Tawil Member above give rough hammocky ground formed by strongly crossbedded sandstone. The third main exposure of the Tabuk at Aṭ Ṭawil where the upper part of the formation (Tawil Member) crops out in a precipitous range of black sandstone hills about 200 m high. The fourth and smallest area is where the Tabuk Formation is exposed north-west of Al-Jauf where the upper part of the formation occurs in the slopes of hills and scarps. In this area the massive sandstone of the Tawil Member is covered by resistant limestone of Cretaceous and Eocene ages.

II

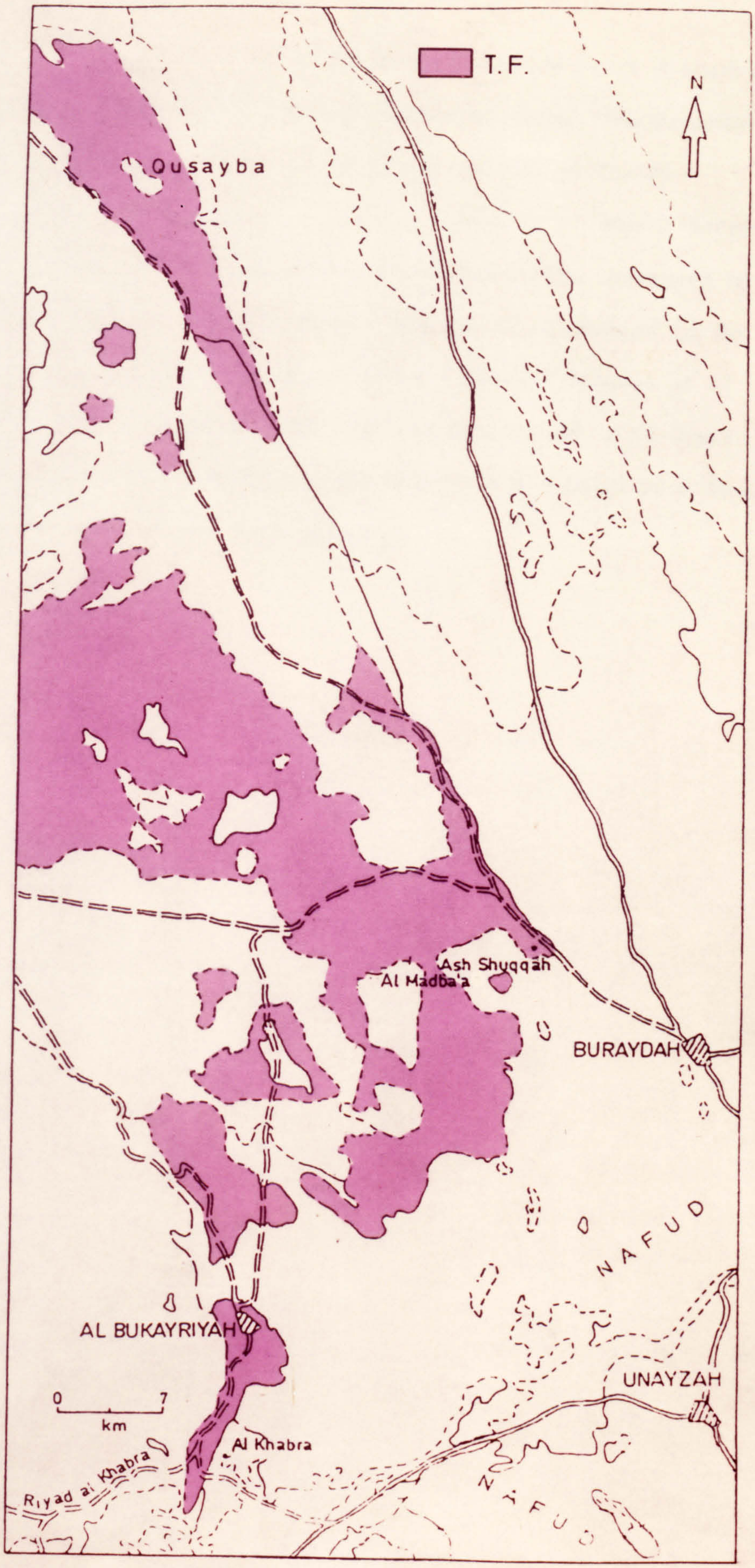
SECTIONS IN THE AL-QASSIM DISTRICT

The area under present study extends north from Al-Khabra near which the lower part of the Tabuk Formation is exposed, to Qusayba where the upper part is present a distance of 92 Km long; between these two localities are exposures of the middle part. This country is located between longitudes 43°30' and 44°00'N and latitudes 26°00' and 27°00'E. It occurs within Wadi Arrimah Quadrangle and almost in the north central part of Saudi Arabia. Generally it is flat land but includes scattered escarpments and part of the An Nafud sand desert. The exposures are accessible from the main roads. Geologically this area is of Ordovician and Silurian age. An initial general reconnaissance of the area was made, followed by designating the sections upon which I worked, measuring and describing the sections, and collecting the fossils.

The rocks of the region are generally not well exposed and where exposures occur there may be extensive weathering, regolith, sand or duricrust. From the many small exposures little information of direct value to this study was obtained and only the major exposures are described below. Figure 6.

Fig. 6 Generalized geological map showing distribution of the Tabuk Formation in Al-Qassim area and location of main sampling areas. (From Bramkamp et al., 1963).

(T. F. = Tabuk Formation).


T.F.
N
Qusayba
Ash Shuqqah
Al Madba'a
BURAYDAH
NAFUD
AL BUKAYRIYAH
UNAYZAH
0
7
km
Al Khabra
Riyad al Khabra
NAFUD

a. Al-Bukayriyah and Al-Khabra Sections.

The exact site of Al-Bukayriyah section is at a quarry near the main road of the town entrance coming from Buraydah. The section exposes whitish, purple, redish, and yellowish trilobitic and graptolitic shale a thickness of approximately 16 m. The age of these strata is Llanvirn Series indicated by graptolites and trilobites; this section is equivalent to the lower part of Tabuk Formation (Handir Member) (Powers et al. 1966, 1968). Similar lithology has been found in Al-Khabra 8 km south of Al-Bukayriyah approximately 6 m thick with very rare poorly preserved _Didymograptus_.

STRATIGRAPHIC COLUMN AT AL BUKAYRIYAH

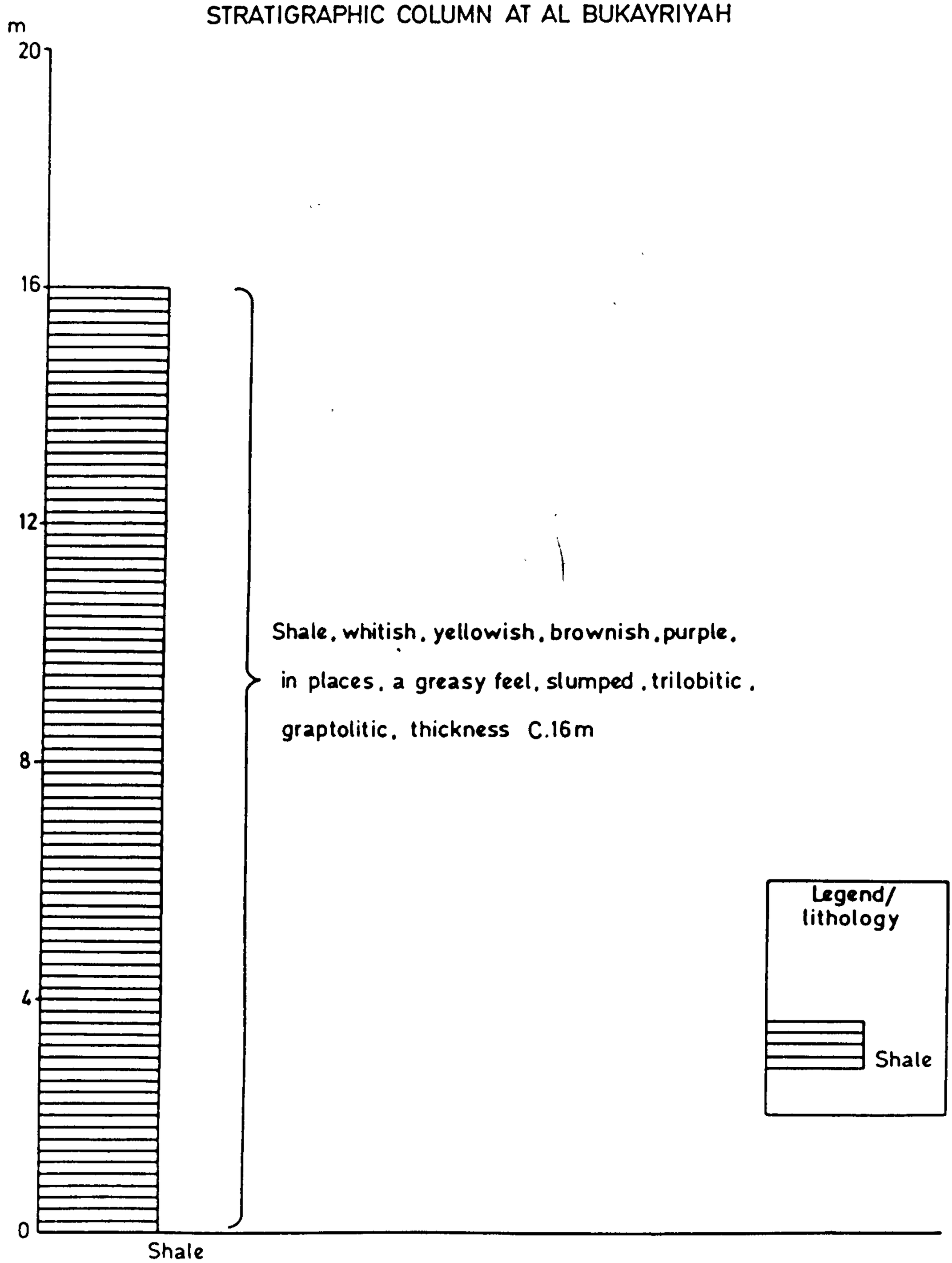


FIG. 7

b. Al-Madbaa section

This section reveals two lithological units, a shale unit in the lower 24 m, and a sandstone unit above. The shale unit is predominantly of greenish grey finely laminated shale. Locally it is purplish and also leached to a yellow colour by the oxidation of disseminated pyrite. Graptolites, though rare, are preserved at several horizons.

The upper unit consists of 7.5 m of thin beds of pure quartz sandstone, white, well sorted and mature. These beds are relatively hard and feature-forming, are crossbeded and ripple-marked, and possess small burrows and other trace fossils poorly preserved. Iron-staining is local. Numerous round concretions up to 5 cm in diameter are abundant in these beds. This lowest sandstone (3 m) bed is massive but succeeded by thinner bedded white sandstone with numerous nearly vertical joints.

STRATIGRAPHIC COLUMN AT AL MADBAA

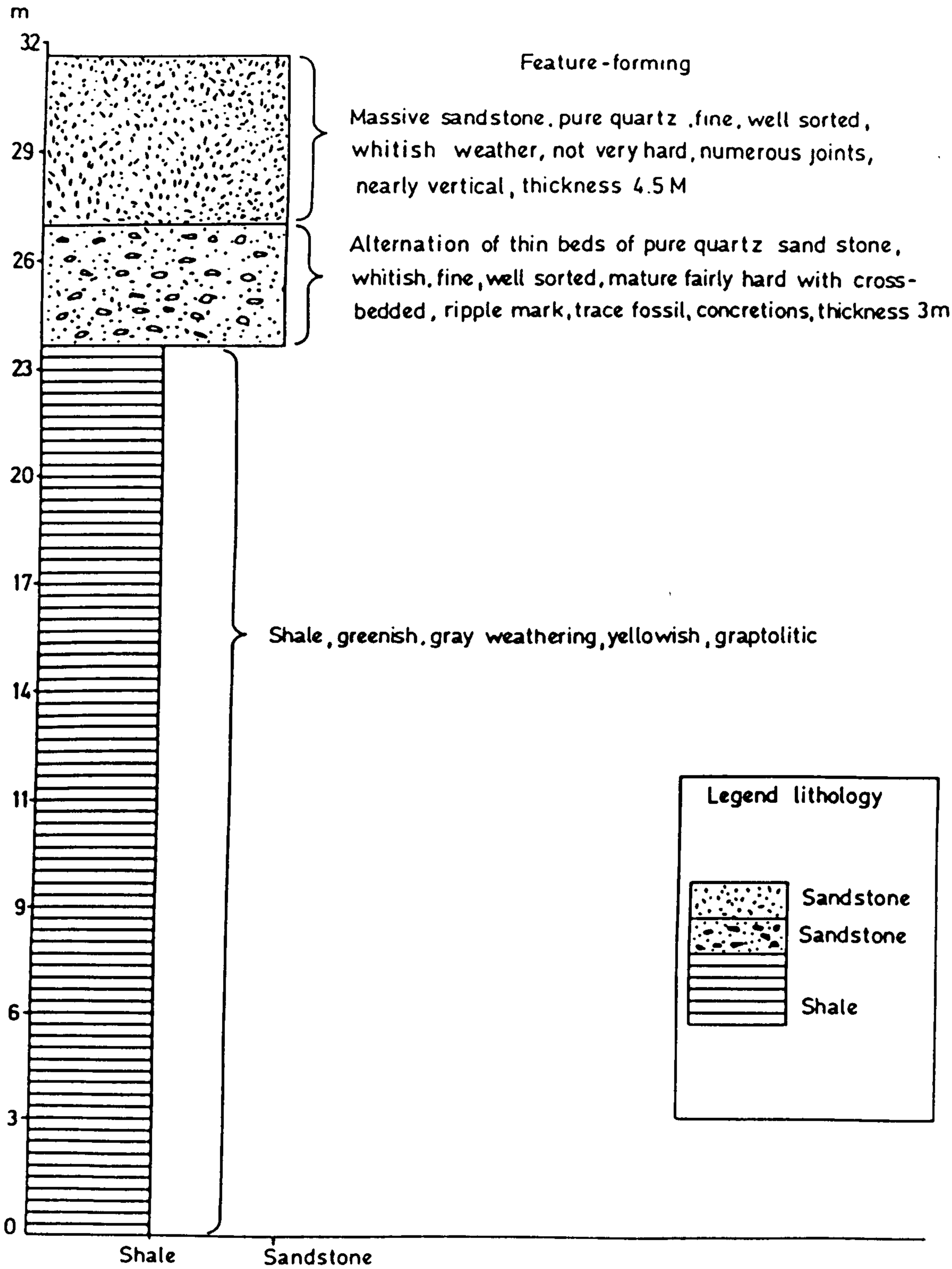


FIG. 8

c. Ash Suggah section

A small out crop of the Tabuk Formation occurs in the vicinity of Buraydah town on the western side of the road from Qusayba, and some 12 Km from the centre of Buraydah. The sequence mainly consists of green shale, greenish, yellowish siltstone, capped by a limestone in all reaching a thickness of approximately 7 m. (See fig. 9).

Despite intensive searching, no faunal evidence from AshShuggah has been found and thus therefore it is difficult to determine its age. However. although the lower beds of this section resemble those seen in the other described sections, the presence of the limestone is puzzling. On lithological grounds, the section at AshShuggah resembles lowermost part of member 5 of the Tabuk Formation type section (Bramkamp et al. 1951).

STRATIGRAPHIC COLUMN AT ASH SHUGGAH

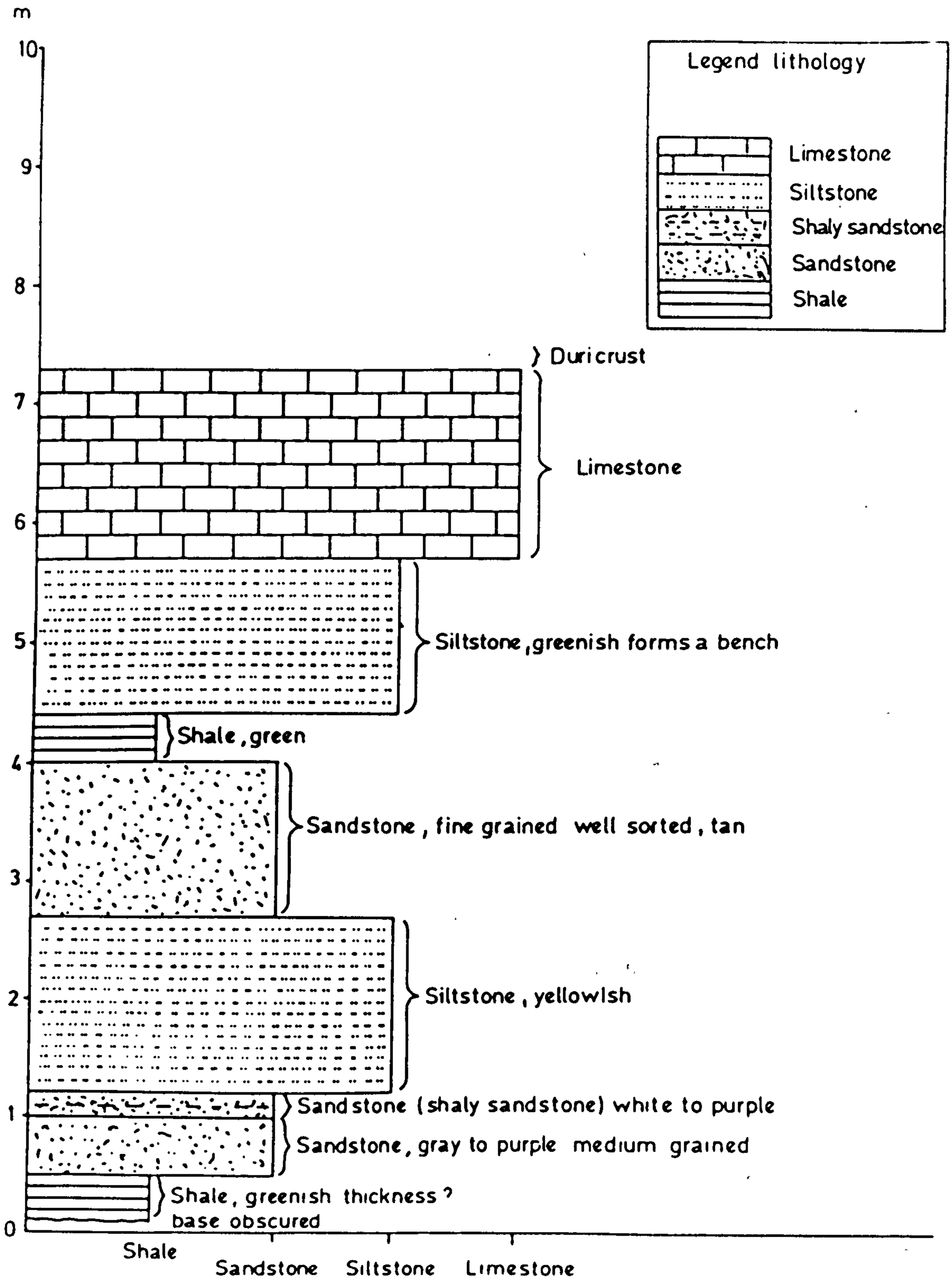


FIG. 9

d. Qusayba section

The sections have been measured at the western end of the long cliff-like exposure, which at Qusayba is approximately 1.5 Km long. Duricrust caps the section and locally run off erodes the top of the section and debris cones obscure the lower part of the section. Generally the section shows a distinct lower part and an upper part. The lower part of the section is predominantly shale; the upper part contains alternations of sandstone and shale. The shales of the lower part of the section are greyish, greenish in places, porcelanous, hard, and fissile in places. They preserve thin films of gypsum cutting the bedding planes. The thickness of these veins is about 2.3 mm; they thickened in the upper beds. Nodules of pyrites, and numerous fossils of graptolites have been observed at some levels in the lower part of the section. The upper part of the section is about 30 m thick, and can be divided into two components (lower, upper). The lower component is about 16 m thick; the percentage of the shale is greater than that of sandstone, while the upper components is the opposite. The sandstone is buff, hard, of subrounded grains and well sorted. The gradation of the sandstone grains are varied, coarser at the lower beds, and gradually becoming finer upwards. Some of the sandstone beds show flame and pull-apart structures at their lower boundaries while others show slumped and balled masses. The trace fossils are preserved on the surface of sandstone beds e.g. Diplocraterion.

The shales in the upper part of the section are greyish, gypsiferous, micaceous in places. Towards the north-west of

the sections a new formation lies over Qusayba section. Its thickness estimated as 25 m. It is sandstone, medium to to coarse-grained, even conglomeratic in places. Bedding varies up to 2 m thick; strongly trough cross-bedded, with the uppermost few centimetres of the cross-sets deformed.

Composition is highly quartzose but with much pyrite weathering to limonite. Trace fossils are the only ones to have been found.

This formation was probably deposited in a high-energy shallow-water environment with many shifting channels cut in coarse sand beds, and accumulating rapidly.

The trace fossils are consistent with a shallow-water environment occupied by a vagrant infauna, and it was perhaps periodically exposed above water level.

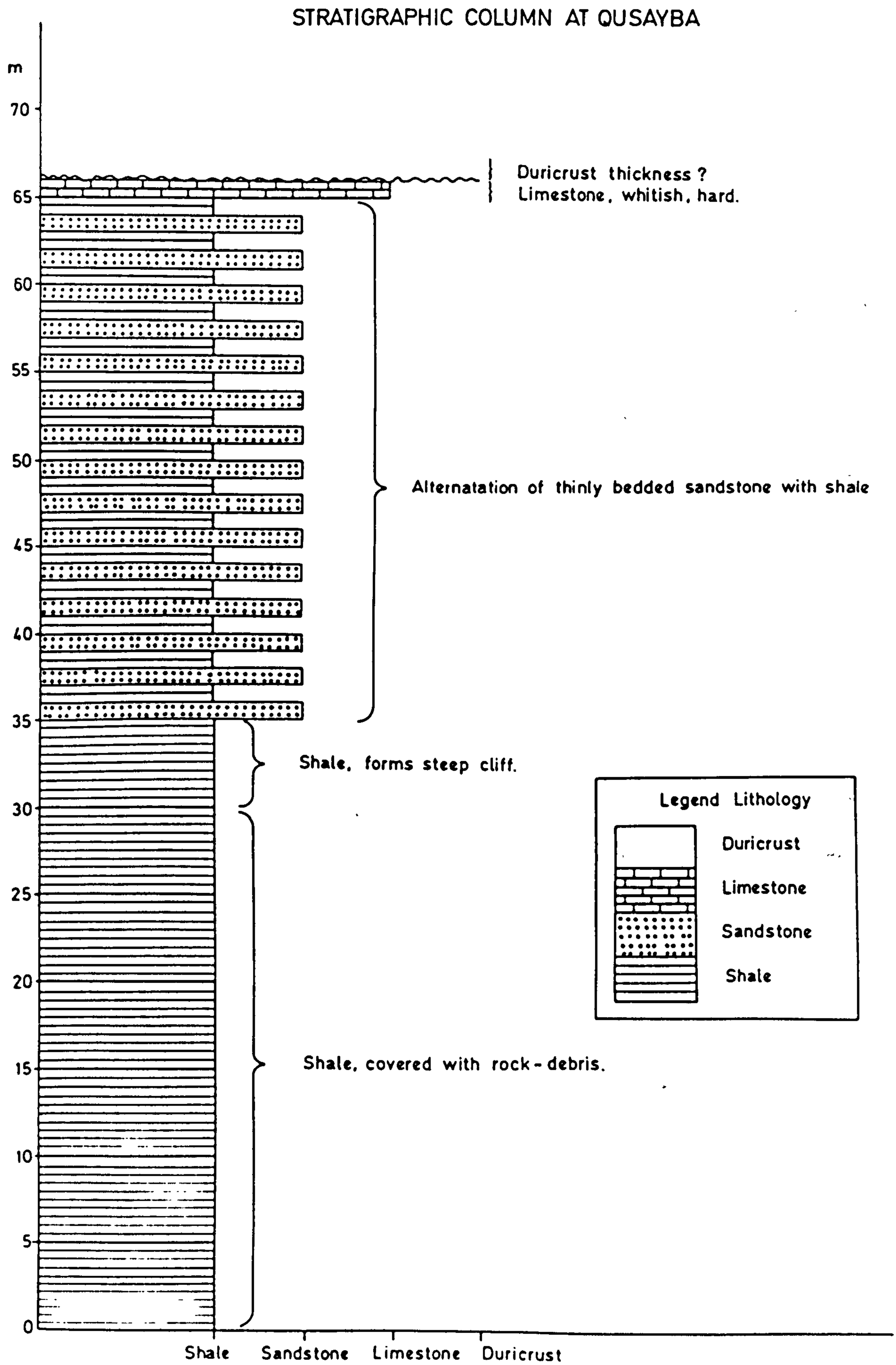
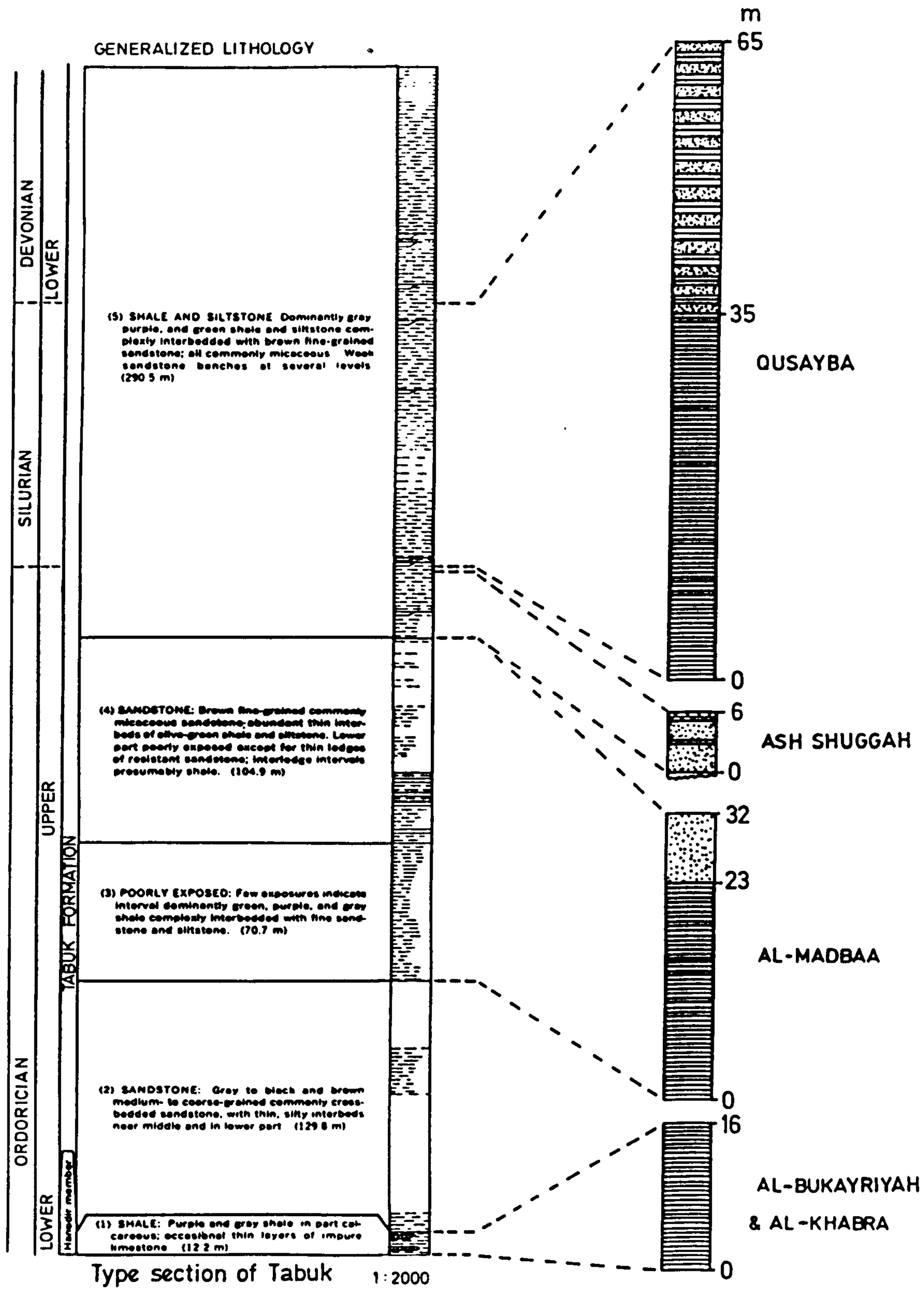

STRATIGRAPHIC COLUMN AT QUSAYBA
m
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Duricrust thickness ?
Limestone, whitish, hard.
Alternatation of thinly bedded sandstone with shale
Shale, forms steep cliff.
Shale, covered with rock-debris.
Legend Lithology
Duricrust
Limestone
Sandstone
Shale
Shale
Sandstone
Limestone
Duricrust

FIG. 10

e. Sedimentology, conditions of deposition and correlation of the sections with the type section.

Details of sedimentology are given in the preceding pages and are consistent with those of cold and shallow-water clastic deposition in the present area. Global transgression and regression, due to sea level changes in the early Palaeozoic left their mark clearly in the region which was tectonically stable. The evidence thus represents several cycles shale and sandstone accumulation in shallow platform environments. The lack of free-carbonate deposits is what one might expect in a region at high latitude.

Correlation of local sections with the type section show that Al-Bukayriah and Al-Khabra are equivalent to Hanader Member, Al-Madbaa to Member 3 & 4, AshShuggah probably to the lower most part of Member 5, and Qusayba to Member 5. This correlation is over a distance of several hundred kilometers and indicate the lateral uniformity of the sediments which is, again, a result of the extensive and uniform sedimentary environment. Such lithological continuity is notable in other parts of the Palaeozoic section on the Arabian Shield, a Devonian age for the (Tabuk) units here cannot be confirmed. The problem of the full biostratigraphic age of all members of the Tabuk remains to be resolved. The present study relates to the local age of the lower membersonly.



Type section of Tabuk formation (not including Member 6 & Tawil Member) (by Bramkamp et al 1951)

FIG. 11 A CORRELATION CHART ILLUSTRATING SECTIONS IN AL QASSIM DISTRICT IN RELATION TO THE TYPE SECTION OF TABUK FORMATION

III

SAMPLING PROCEDURES AND PREPARATION TECHNIQUES

a. Sampling stratigraphic sections.

In the search for fossils in the study area, most of strata have yielded negative results. Therefore a large amount has been collected of unweathered fresh samples within 2-3 m intervals, ascending from the base of each section. Over 200 samples, 250-500 g in weight carefully wrapped with paper, were packed and brought for study in the lab. A careful and intensive search for fauna was made but the absence of fossils is in general an indication of unsuitable conditions for life at that time.

Where a fossiliferous bed was discovered it was traced laterally as far as exposure or accessibility allowed.

b. Preparation techniques - macrofossils/microfossils

TRILOBITES

Techniques:-

Standard techniques have been applied in preparing the fossils, all specimens being cleaned of matrix with the aid of a Burgess Vibro-tool, together with needles and brushes under a binocular microscope.

Photography:-

Photographs have been taken of most of the specimens by a Nikon 35 mm reflexed camera with 55 mm microlens. Small specimens have been photographed under a Zeiss microscope with a Tessovar photomacrographic Zoom System. The specimens were covered with a light dusting of ammonium chloride sublimate. All the photographs were taken by fibre-optic cold light illumination. The negatives are on Ilford FP4 125 A.S.A, and the prints are on Ilforspeed paper (grade ranges between 2 - 3).

GRAPTOLITES

Techniques:-

Preparation of specimens depends upon the nature of the fossils and the matrix. Those found in the Al-Qassim area are preserved in flattened or very low relief form - as thin films of carbonized material in a shale. However little can be done, apart from a careful cleaning of the fossils with a fine needle under a binocular microscope and then covering the specimens by a varnish in order to obtain better visual contrast between the matrix and the fossils.

Illustration:-

Illustration of the graptolites in the present study is based on drawings over an enlarged photographic print at approximately ten times of the original size.

Photography:-

Photographs have been taken by a 35 mm Nikon F2 Photomic camera for most of the specimens, and for small specimens the photographs have been taken under a Zeiss microscope with a Tessovar photomacrographic Zoom System. For better results it is advisable to cover the specimens with alcohol (Ethanol, Methanol) to increase the contrast between the fossils and surrounding matrix.

PALYNOMORPHS

Treatment of samples:-

The aim in the preparation of samples is to concentrate and extract acritarchs and spores present and to render them as visible as possible. Since the palynomorphs are composed of organic compounds (condensed fatty acid derivatives), they may be extracted from the matrix by hydrofluoric acid and hydrochloric acid treatment. The samples examined did not contain carbonate and so were treated directly with hydrofluoric acid.

Ten samples were collected from the section of Qusayba, Al-Madbaa, and Al-Bukayriah; a few grammes of each were examined separately. The procedure followed was:-

1. Sample was crushed to fragments of approximately 0.5 cm diameter.
2. Sample was covered by hydrofluoric acid in polythene beaker (100 ml) and allowed to rest for 3-4 weeks, the acid was agitated every day and more added as required until the sample was disaggregated.
3. The sludge then was washed, centrifuged for 5 minuted several times to remove acid.
4. The residue was then placed in hydrochloric acid for 1-3 days
5. Washing in distilled water, and centrifuging was also repeated to remove acid.
6. Suspension of residue was filtered to concentrate the fossil content.
7. Filtered material was mounted on slides in xylol-soluble mounting or in mounting medium D.P.X., and cover slips applied.

5. Washing in distilled water,and centrifuging was also repeated to remove acid.
6. Suspension of residue was filtered to concentrate the fossil content.
7. Filtered material was mounted on slides in xylol-soluble mounting or in mounting medium D.P.X., and cover slips applied

Photomicrography:-

Two different microscopes were used for the photomicrography throughout the study.

1. Leitz Orthoplan 715334 with automatic camera, set at 18 din (50 ASA) for Kodak Ektachrome. (In Botany Dept., Bristol).
2. Kyowa Midlux also set at 18 din (50 ASA) using illumination.

Colour slide film was used to obtain (print) the best possible illustrations.

c. Repository of material:-

All specimens which provide material for the present study are now housed in the Geology Department of Bristol University. Kindly, this department of Bristol will allow the future transfer of the specimens to the Geology Museum of King Abdul-Aziz University, Jeddah, Saudi Arabia which museum will soon be established.

IV

SYSTEMATIC

PALAEONTOLOGY

1. Macrofossils

a. Trilobites

The following trilobites are described below

- Hanchungolithus cf. primitivus (Born, 1921).
- Neseuretus tristani (Desmarest, 1817).
- Plaesiacomia cf. vacuvertis Thomas, 1977.
- Platycoryphe cf. dyaulax Thomas, 1977.
- Calymene sp.

They represent Ordovician and Silurian times and the genera Neseuretus, Hanchungolithus are locally abundant. Preservation ranges from good to poor, dependent upon matrix but most specimens are disarticulated fragments. Complete or nearly complete specimens are rare.

Method of study:-

In the descriptions of the trilobites found during the present study the terminology follows mainly that in the 'Treatise of Invertebrate Paleontology' part (O), Arthropoda 1 (Moore, 1959). Additionally, a few other terms are introduced viz: arc = concentric row (Hughes, 1970), and I_n = the innermost arc (Ingham, 1970). Most measurements were made by means of a binocular microscope with a graticule eye-piece, other measurements were made with a Vernier caliper.

Systematic description:-

The classification of the trilobites used in this study is also mainly based on the 'Treatise on Invertebrate Paleontology' part O, Arthropoda 1 (Moore, 1959). For the determination of Hanchungolithus, I have followed Dean's classification (1966).

Family TRINUCLEIDAE Hawle & Corda, 1847

Subfamily HANCHUNGOLITHINAE Lu, 1963

Genus HANCHUNGOLITHUS Lu, 1954

Type species:- Cryptolithus multiseriatus Endo, 1932

Hanchungolithus cf. primitivus (Born, 1921)

Pl. 1, figs, 1-6, Text-fig. 1a-b.

1921 Trinucleus primitivus Born: 191, fig.1.

1957 Myttonia primitiva (Born) Whittard: 267, pl.1, figs.1-5.

1963 Hanchungolithus primitivus (Born) Lu: 338.

1964 Hanchungolithus primitivus (Born); Lu:293.

1966 Hanchungolithus primitivus (Born), Dean:281, pl.5,figs.1-9.

Material:-

More than seventy fragments of this species were recovered, of which the following are counted, fifty cephala and nineteen pygidia.

Locality and geological horizon:-

Al-Bukayriah quarry north central Saudi Arabia, 26°10'N, 43°40'E. Llanvirn Series, Tabuk Formation.

Description:-

The cephalon is subrectangular in outline with rounded anterolateral corners; the breadth of the cephalon is twice the length. The glabella is pyriform, and stands higher than other parts of the cephalon. The longitudinal profile of the cephalon shows a deflection of the glabella anteriorly through an angle of about 55°. Three pairs of small, shallow, faintly furrows present clearly on the steeple inclined sides, scarcely visible

on some specimens. Axial furrows are sigmoidal, deepest anteriorly towards the anterior fossulae, widening towards the alar lobes, and hardly defined posteriorly. The alar furrows are very shallow, faint meet the posterior border furrow posteriorly and the axial furrows anteriorly. The alar lobes are sub-triangular in outline, slightly raised and convex. The occipital ring has no occipital spine and is protruding slightly backwards. Posterior border furrows extend towards the lateral sides and curve slightly backwards at their terminations into posterior fossulae; the posterior border is thin, widening laterally and slightly curved towards the posterior fossulae. Genal lobes are a quarter-circle in outline, moderately convex and carry a small lateral eye tubercles with faint eye ridges join the axial furrows at the level of about the third of glabella furrows and the eyes; from the end of the eye ridge appears a delicate, faint unbranched nervure extends towards the corner of the cheek-lobe. The fringe is confined by a marginal band which raised above the flat surface of the fringe becoming more prominent laterally, the fringe is narrower frontally widening anterolaterally and laterally, having at the post-lateral end of the fringe a genal spine which is about twice as long as the axial measurement of the cephalon; the genal spines extend backwards then inwards near the ends.

There are no pits outside a marginal band. The incomplete fringe-formula is I_1 1-6, I_n 2-6, I_2 4-6; the remainder of the formula cannot be given because beyond R_6 the radial arrangement of the pits breaks down;I_1 contains about 20 pits in the half-fringe; there is a slight irregularity in their disposition. The total number of the pits is about 84 in the half-fringe. Marginal suture passes along marginal band. No specimens of the thorax have been found. The pygdium in H. cf. primitivus is sub-triangular in

outline with steep border declined towards lateral and posterior sides; becomes narrower anterolaterally; the width is about 2½ as long as the axial length; fine terrace-lines are present on the deflected border. The axis is bounded laterally by axial furrows, it is narrowing towards the rear. The axis is divided by three clear axial furrows. The upper surface of each pleural lobe is slightly concave laterally and the lobes narrow towards the lateral sides; depressed towards the steep border. No pleural furrows have been observed.

Remarks:-

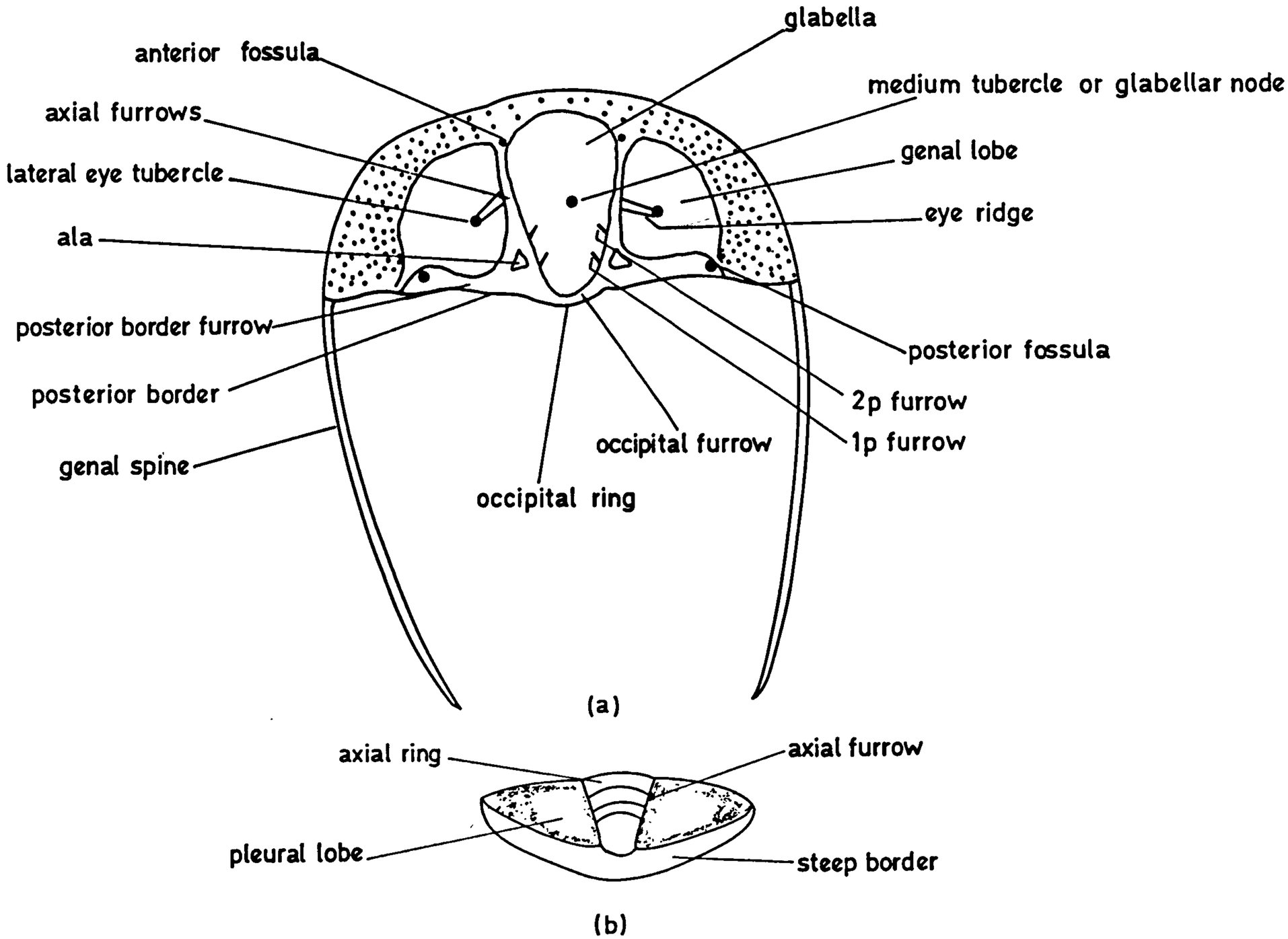
I agree with Dean (1966) that H. primitivus and H. multiseriatus are not synonymous. Several disarticulated fragments of cephala, cranidia and pygdia have been found but it is difficult to assign them to their developmental stages. H. cf. primitivus differs from H. primitivus in size and in the number of the pits. eg. breadth = 10.5 mm, length = 4.5 mm. I_1 does not have more than 22 pits, while the same size (breadth = 10.4, length = 4.5) H. primitivus (Born) Whittard (1957), I_1 does not have less than 35 pits in the half-fringe. The age of the rock which have yielded H. cf. primitivus is Llanvirn. Brenchley et al, (1967). considered H. aff. primitivus from south-eastern Ireland as Arenig in age, and Dean (1966) referred H. primitivus from south-eastern France to the Lower Arnig.

RECONSTRUCTION OF CEPHALON & PYGIDIUM OF

Hanchungolithus cf. *primitivus*

Text-fig. 1 a- based on B1309a, internal mould of cephalon, Al-Bukayrîah, x 9.

b- based on B138, internal mould of pygidium, Al-Bukayriah, x 8.


glabella
anterior fossula
medium tubercle or glabellar node
axial furrows
genal lobe
lateral eye tubercle
eye ridge
ala
posterior border furrow
posterior fossula
posterior border
2p furrow
occipital furrow
1p furrow
genal spine
occipital ring
(a)
axial ring
axial furrow
pleural lobe
steep border
(b)

Family CALYMENIDAE Burmeister, 1843

Genus NESEURETUS Hicks, 1873

Type species:- Calymene parvifrons var. murchisoni Salter, 1865

Neseuretus tristani (Desmarest, 1817)

Pl. 2, figs. 1-10; Text-fig. 2a-d.

For synonyms see Henry (1970, 1980) and Sadler (1974).

Material:-

More than two hundred fragments have been found, of which the following are counted, eighty four cranidia, twenty three free cheeks, eleven hypostoma, ten thoracic segments, sixty seven pygidia and one almost complete exoskeleton.

Locality and geological horizon:-

Al-Bukayriah quarry, Al-Qassim north central Saudi Arabia, 26°10'N, 43°40'E. Llanvirn Series, Tabuk Formation.

Description:-

The cephalon is almost semicircular in outline, having a frontal protuberance; the posterior edge is mostly straight, the cheek angles protruding slightly backward. The total length is about half of the width. The glabella is bounded laterally by well marked axial furrows. They converge forward following an angle of about 40°. There are three pairs of glabellar furrows of which the posterior furrows are wide and deep becoming concave towards the rear then going up again; they become progressively weaker towards the median lateral lobes. The middle glabellar furrows are incisions declined slightly backward. The anterior glabellar furrows are the weakest, scarcely visible in some specimens. The posterior lateral glabellar lobes are convex, having an axe blade-like shape, they bear on their base semi-circular marks of muscular insertion. The median lateral lobes are roughly rectangular,

widening towards the glabella axis. The anterior lateral lobes are often unapparent. The frontal lobe is flattened subrectangular, about three times as broad as long; it bears laterally a pair of anterior pits of funnel shape placed between the anterior glabellar furrows and hypostomal pits. These pits are described by Whittard in N. brevisulcus as "adventitious pits" (Whittard, 1960, p.146, Pl.XIX, fig.7,8). The axial zone of the glabella is free of furrows, flat, or slightly convex. The occipital furrow is well marked widening in the middle, narrowing and deep laterally. The occipital ring is of constant width and lacking a mesial tubercle. In the longitudinal profile of the cranidium the glabella falls regularly in a fairly steep slope towards the pre-glabella furrow. The anterior area is large, swelling, moderately convex, bounded laterally by two wide furrows diverging an obtuse angle, mingling with the lateral border furrows of the cheeks. The frontal protuberance is faintly indicated.

The posterior border furrows are concave widening in the middle. The alae are well developed on either side of the glabella, at the level of the posterior lateral lobes, in the form of two semi-circular areas. The eyes, raised on short peduncles, are at the level of the anterior lateral lobes. The palpebral lobes are hardly distinguishable. The ocular ridges join the lateral glabellar furrows at the level of about the

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anterior glabellar furrows and the eyes. The facial suture is gonatoparian. The posterior section of it describe as a curve start from the eye as concave then convex towards the genal angles; the anterior sections intersect the cheek's protuberances on both sides. The hypostoma is twice as long as it is wide; the median body is oval and convex divided into two lobes by median furrow. The posterior lobe is the smaller, swollen, and crescent-shaped. This region in Henry's material (Henry, 1970) carries two voluminous maculae which is not seen here; it may be the result of a bad preservation. The anterior lobe the larger is concave and ovoid. In the front of the anterior lobe a vast flattened slightly concave area spreads. The posterior border is narrow mesially. The thorax is constituted of 13 segments. The axial rings are slightly convex towards the front, narrow in their median part, laterally swell. The pleura has a fulcrum and is divided by a deep pleural furrow. The posterior forms a protuberance in its proximal part. The protuberance diminishes progressively towards the distal extremity. The latter is laterally widened and flattened. Its spatula-shape facilitated the encasing of the pleural during rolling up.

The micropygous pygidium is roughly triangular in outline. The width is larger than its length. The axial region is laterally edged by two deep axial furrows. There are six axial rings (In Henry's specimens 7). The terminal piece bears two faint ring marks. The pleural regions are convex, well marked segmentation by four pleural furrows. The pleural region consists

of four ribs each one is divided by finer interpleural furrows commence from about the middle part towards the margin of the pygidium.

RECONSTRUCTION OF CEPHALON, HYPOSTOMA & PYGIDIUM OF

Neseuretus tristani (Desmarest, 1817)

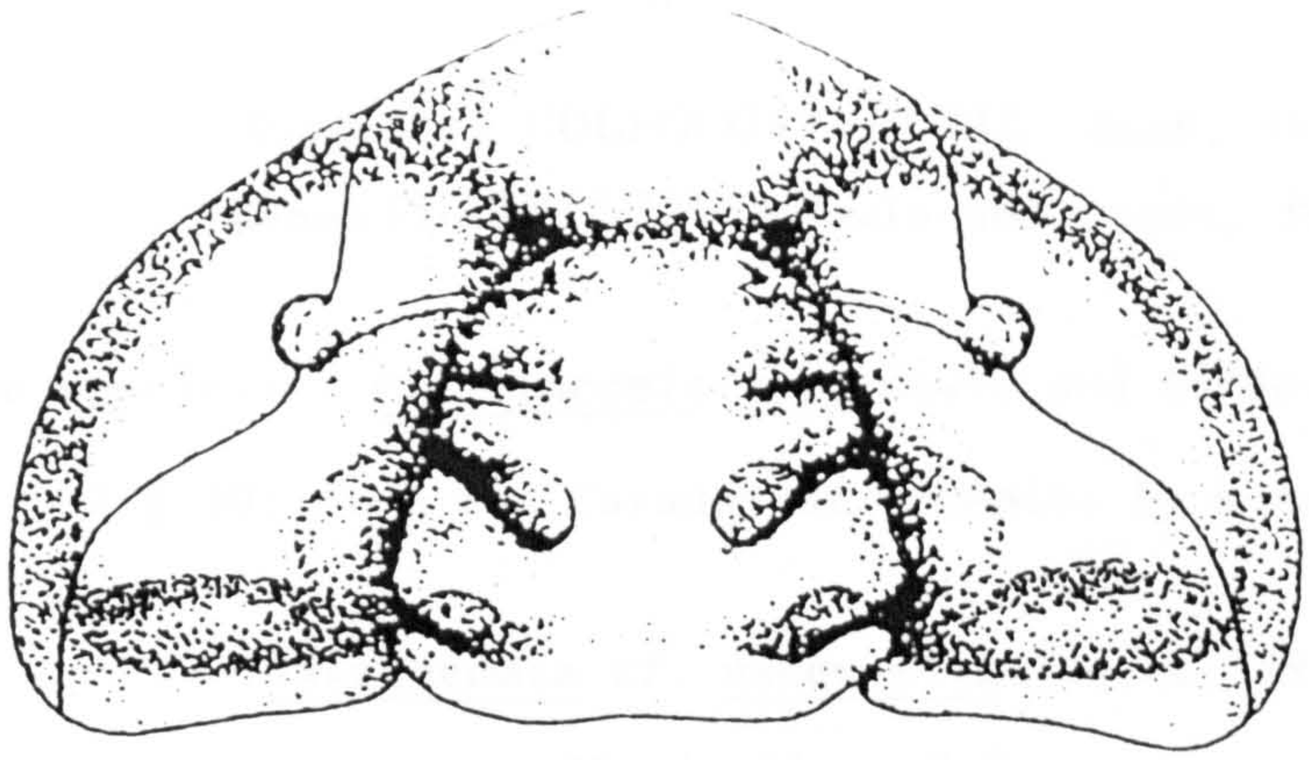
(After Henry, 1970)

Text-fig. 2 a- BN37, internal mould of cephalon, dorsal view, loc. Al-Bukayriah, x 3.7.

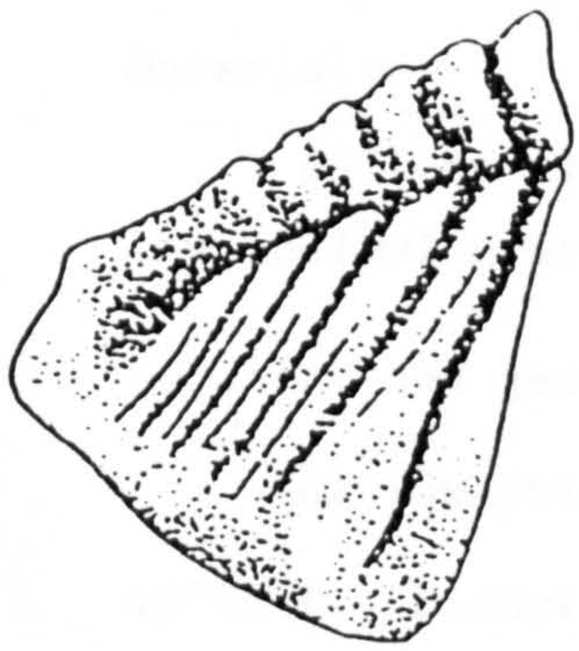
b- BN23, internal mould of pyidium, lateral view, loc. Al-Bukayriah, x 2.7.

c- BN23, dorsal view, loc. Al-Bukayriah, x 2.7.

d- BNOTA, internal mould of hypostoma, dorsal view, loc. Al-Bukayriah, x 4.4.

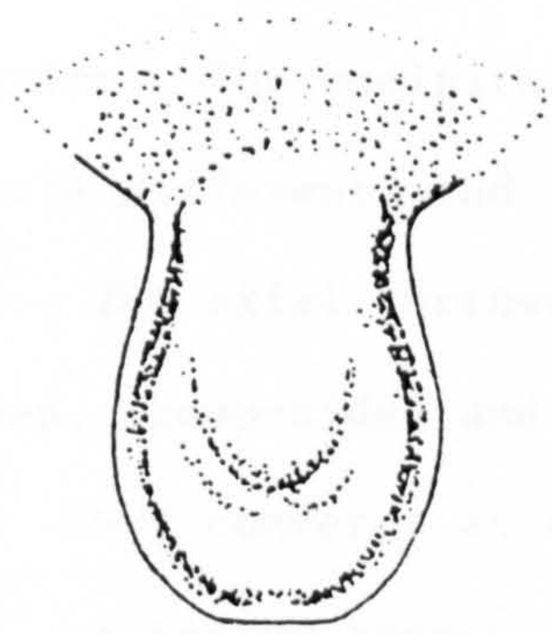


(a)



(b)

(c)



(d)

Subfamily COLPOCORYPHINAE Hupé, 1955

Genus PLAESIACOMIA Hawle and Corda, 1847

Type species:- Plaesiacomia rara Hawle and Corda, 1847, p.55, pl.3, fig.30; from the Caradoc of Bohemia; by monotypy.

Plaesiacomia cf. vacuvertis Thomas, 1977

Pl. 1, figs. 7-9.

1977 Plaesiacomia vacuvertis Thomas, pp.164-166, pl.23, figs. 6,8-11; pl.24, figs.1-6.

Material:-

Sixteen fragments of this species have been found of which the following are counted, ten cranidia and six pygidia.

Locality and geological horizon:-

Al-Bukayriah quarry, north-central Saudi Arabia 26°10'N, 43°40'E. Llanvirn Series. Tabuk Formation.

Description:-

The cephalon is semicircular, steeply declined anteriorly and laterally. The glabella is smooth, gently convex and tapers towards the anterior. The occipital furrow is slightly wide (Sag.), but clearly differentiated from the glabella by the occipital furrow. The axial furrows and pre-glabella furrow are well defined, deep, steep-sided and the axial furrows are shallowing posteriorly. They converge at approximately 45° with the occipital furrow. A narrow border is developed anteriorly. The palpebral lobes appear to be placed a little more than half the way along the cephalon from the posterior margin. Although

glabellar furrows were reported in the type material, they cannot be seen in the fossils here. Para glabellar areas cannot be seen in the present specimens due to bad preservation. The posterior border is the same width (exsag.) as the occipital ring, widening abaxially. A clear posterior border furrow is present. The diamond-shaped pygidium is about one and a half times as wide as long. The axis is wide anteriorly, convex, divided by four or possibly five faint axial ring furrows. The axis, bounded by the axial furrows, is wide anteriorly and somewhat narrower posteriorly. The pleural fields are triangular in outline with two very faint pleural furrows. The pleural field appear not to extend posteriorly as far as the axis. The pygidial border is broad, almost vertically inclined, and narrows somewhat beneath the posterior tip of the axis.

Family EOHOMALONOTIDAE Hupé 1955

Genus PLATYCORYPHE Foerste 1919

Type species:- Calymene platycephala. Foerste. 1910. pp.81-82, pl.2, fig.7; pl.3, fig.21; from the Trenton (middle Ordovician) of Clifton, Tennessee; by monotypy.

Platycoryphe cf. dyaulax Thomas, 1977

Pl. 1, figs. 12, 13

1977 Platycoryphe dyaulax sp. nov. Thomas; pp.169-171, pl.24,figs.7-9, 11.

Material:-

Internal and external mould of cranidium and four pygidia have been found.

Locality and Geological Horizon:-

Jebel Anter, Qusayba section, Al-Qassim, Tabuk Formation convolutus Zone, Idwian Stage, Llandovery Series.

Description:-

The cephalon is subtriangular, slightly less twice as wide as long, rounded anteriorly. Breadth (br.) of the occipital ring is slightly less than half the maximum cephalic width and slightly greater than the glabellar length. The occipital ring is bounded anteriorly by well-defined occipital furrow. Occipital furrow is slightly narrow abaxially; broader and shallow along the Sagittal line. Axial furrows are broad and shallow. The glabella narrows anteriorly to slightly more than half its posterior width; posterior border is about the same width (ex sag.) as the occipital ring, broadening slightly abaxially. Posterior border furrow is broad and shallow. The frontal area is flat and wide (tr.)

The pygidium is slightly wider than long, rounded posteriorly. The axis is infundibular, poorly defined. Axial ring furrows are faint and shallow. The pleural furrows are faint and directed slightly backwards to the pygidial margin.

Remarks:-

Platycoryphe cf. dyaulax generally agree with previous descriptions of Platycoryphe dyaulax, but 1p and 2p are hard to be seen perhaps due to the poor preservation of the specimen.

Family CALYMENIDAE Burmeister, 1843
[= Calymmenidae Angelin, 1854]

Subfamily CALYMENINAE Burmeister, 1843
[non. transl. Hupe, 1955 (ex Calymenidae Burmeister, 1843)]

Genus CALYMENE Brongniart, 1822 *

Type species: Calymene blumenbachii Brongniart, 1822; Wenlock Series, Much Wenlock Limestone Formation. Dudley, West Midlands, England.

Calymene sp.
Pl. 1, figs. 10-11.

Material:-

One incomplete cranidium.

Locality & Horizon:-

Jabal Antar, Quayba, Al-Qassim, Landovery Series, Tabuk Formation.

Description:-

The glabella is convex, with three pairs of lateral glabellar lobes; the glabella is bell-shaped and as long as wide; it stands high above the fixigenae. The width of the glabella at 1p lateral lobes is 1.5 times the width of the glabella at its frontal lobe. In lateral profile the glabellar surface is horizontal from occipital furrow to approximately furrow 2p, then falls very gently to the anterior margin of the frontal lobe. Axial furrows are very shallow at the occipital ring, narrower and deeper towards 1p, 2p,and 3p. The occipital ring is moderately convex (sag. and exsag), falls very steeply anteriorly and narrows behind 1p lateral lobe towards the axial furrows. The occipital furrow is V-shaped, widens medially and narrows towards the ends. The pre-glabellar furrow is short and shallow; its anterior slope rises fairly steeply to the anterior margin. Anterior margin is straight (sag.), and weakly arched (exsag.). The posterior

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*But see Whittington. Bull. Zool. Nom. 40, p.173, 1983.

border furrow is very wide at midway between axial furrow and genal angle.

Remarks:-

Calymene sp. is in general similar to Calymene lawsoni Shirley (1932); but apart from one incomplete cephalon, it is difficult to assign to that species.

EXPLANATION OF PLATE I

Note: All specimens dusted with ammonium chloride.

Hanchungolithus cf. primitivus (Born)

Fig. 1 B1318a, cephalon, dorsal view of internal mould showing genal spines, loc. Al-Bukayriyah, x 5.

Fig. 2 B1309a, cephalon, dorsal view internal mould showing eye ridge, alar lobes, unbranched nervure, loc. Al-Bukayriyah, x 8.

Fig. 3 B1317, cephalon, dorsal view of internal mould, loc. Al-Bukayriah, x 5.

Fig. 4 B1320, cephalon, dorsal view of internal mould, loc. Al-Bukayriah, x 8.5.

Fig. 5 B1312a, cephalon, dorsal view of internal mould showing glabellar fine reticulate ornament, thick rim, loc. Al-Bukayriah, x 5.4.

Fig. 6 B138, pygidium, dorsal view of internal mould, loc. Al-Bukayriah, x 7.6.

Plaesiacomia cf. vacuvertis Thomas

Fig. 7 BD3a (4), internal mould of cranidium, dorsal view, loc. Al-Bukayriah, x 7.6.

Fig. 8 BD40, internal mould of cranidium, dorsal view, loc. Al-Bukayriah, x 7.6.

Fig. 9 BN20, internal mould of pygidium, posterior view, loc. Al-Bukayriah, x 8.8.

Calymene sp.

Fig. 10 q_4TC01, internal mould of cranidium, dorsal view, loc. Jabal Antar, Qusayba, x 2.

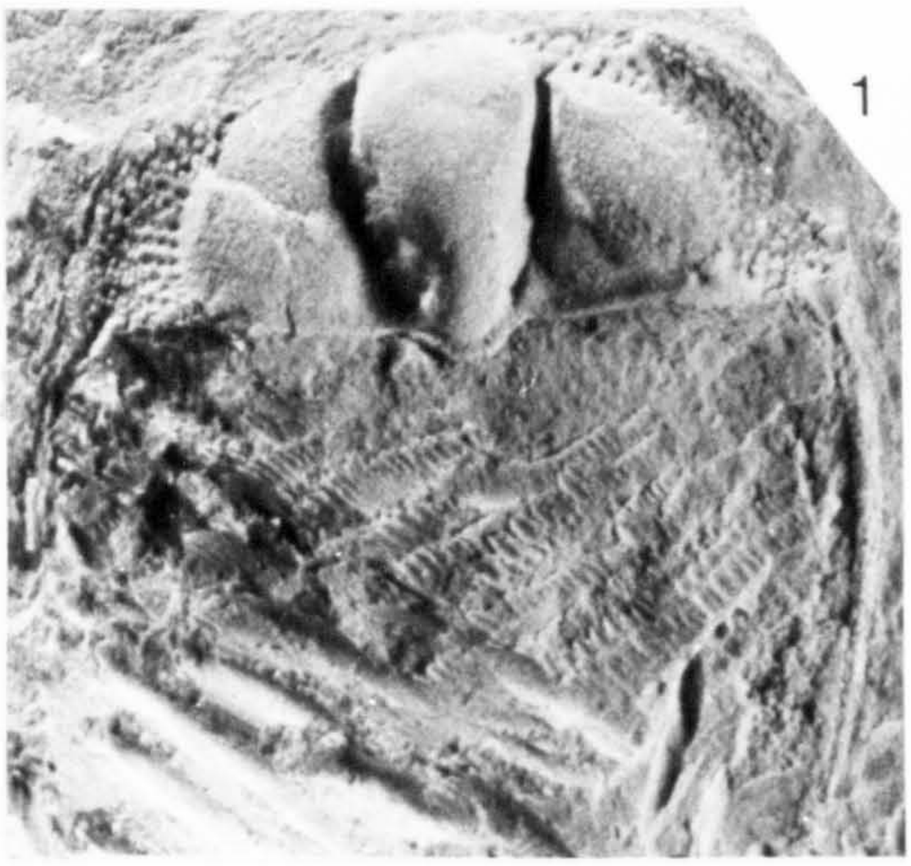
Fig. 11 q_4TC01, internal mould of cranidium, longitudinal profile, loc. Jabal Antar, Qusayba, x 3.2.

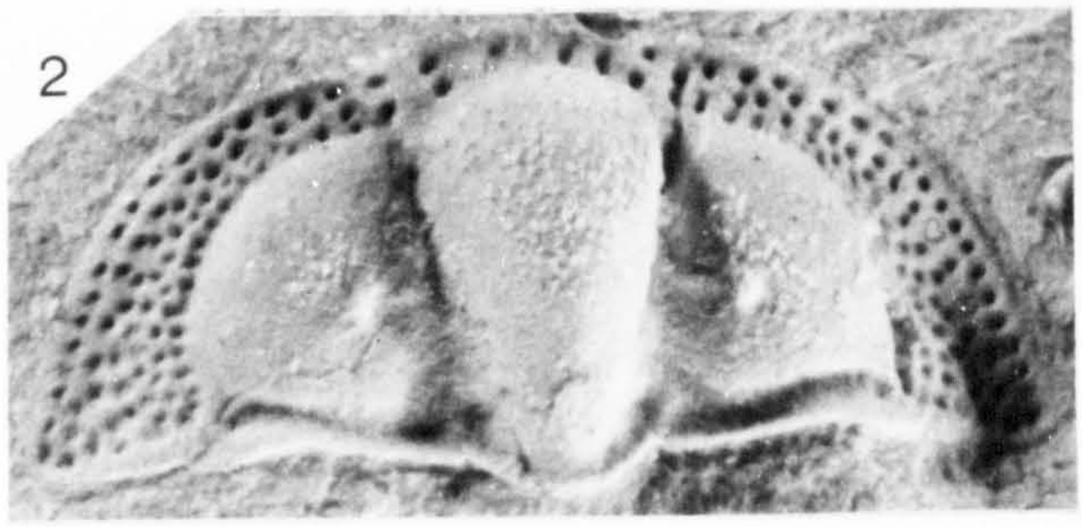
Platycoryphe cf. dyaulax Thomas

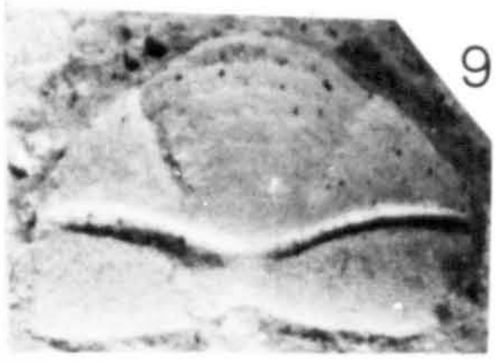
Fig. 12 q_3TP01A, internal mould of cranidium, dorsal view, loc. Jabal Antar, Qusayba, x 2.4.

Fig. 13 q_3TP02A, internal mould of pygidium, dorsal view, loc. Jabal Antar, Qusayba, x 5.5.

Plate 1







EXPLANATION OF PLATE 2

Note: All specimens dusted with ammonium chloride.

Neseuretus tristani (Desmarest)

Fig. 1 BN01a, internal mould of almost complete exoskeleton, dorsal view, loc. Al-Bukayriah, x 5.4.

Fig. 2 BN031, internal mould of hypostoma, dorsal view, loc. Al-Bukayriah, x 10.

Fig. 3 BN07A, internal mould of hypostoma, showing flattened area, dorsal view, loc. Al-Bukayriah, x 4.3.

Fig. 4a-b BN30, internal mould of cranidium, a- showing marks of muscular insertion, dorsal view, loc. Al-Bukayriah, x 1.3, b- longitudinal profile of same specimen, showing flat glabella, x 1.2.

Fig. 5a-c BN31, a- internal mould of cranidium, dorsal view, loc. Al-Bukayriah, x 1.6, b- longitudinal profile of same specimen, showing slightly convex glabella, x 1.8 , c- same specimen showing hypostomal pits, x 2.2.

Fig. 6 BN37, internal mould of cephalon, dorsal view, loc. Al-Bukayriah, x 2.2.

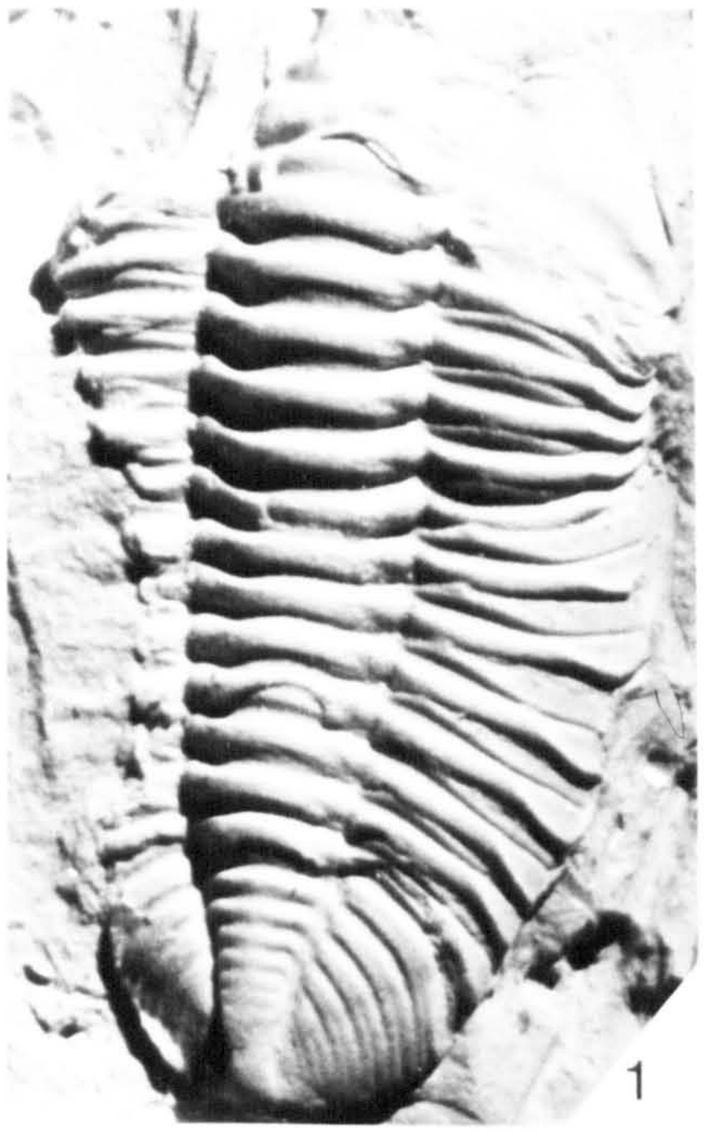
Fig. 7 B351 (1), internal mould of free cheek, dorsal view, loc. Al-Bukayriah, x 1.8.

Fig. 8 BN02a, internal mould of thorax partly enroled, dorsal view, loc. Al-Bukayriah, x 1. (Photograph inverted).

Fig. 9 BN35, impression of external mould, showing occular ridges, dorsal view, loc. Al-Bukayriah, x 1.4.

Fig. 10a-b BN23, a-internal mould of pygidium, dorsal view, loc. Al-Bukayriah, x 2.3, b- same specimen, lateral view, x 2.4.

Plate 2


1

2

3

4a

4b

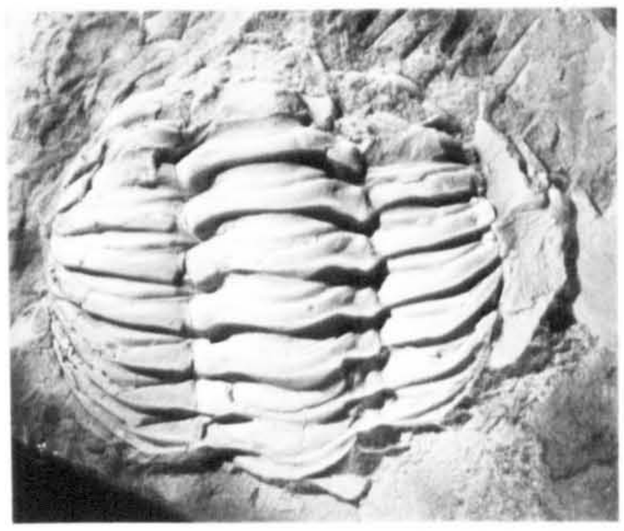
5a

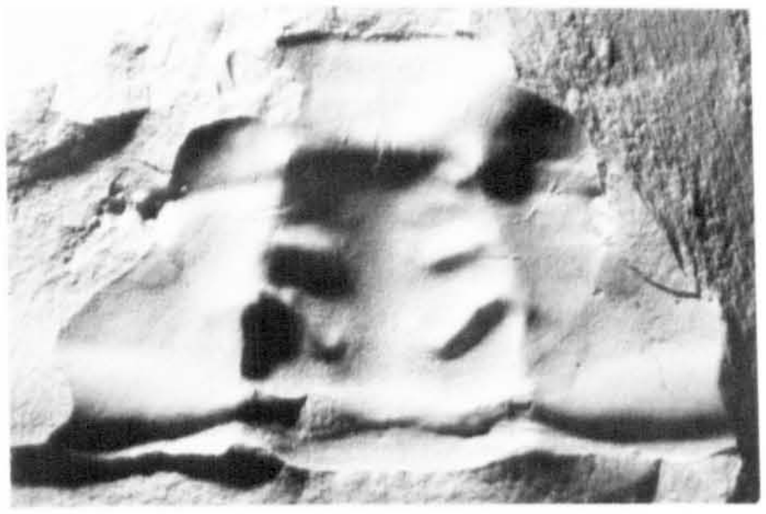
6

5b

7

8

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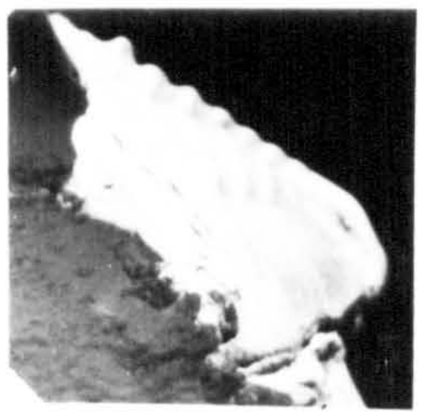
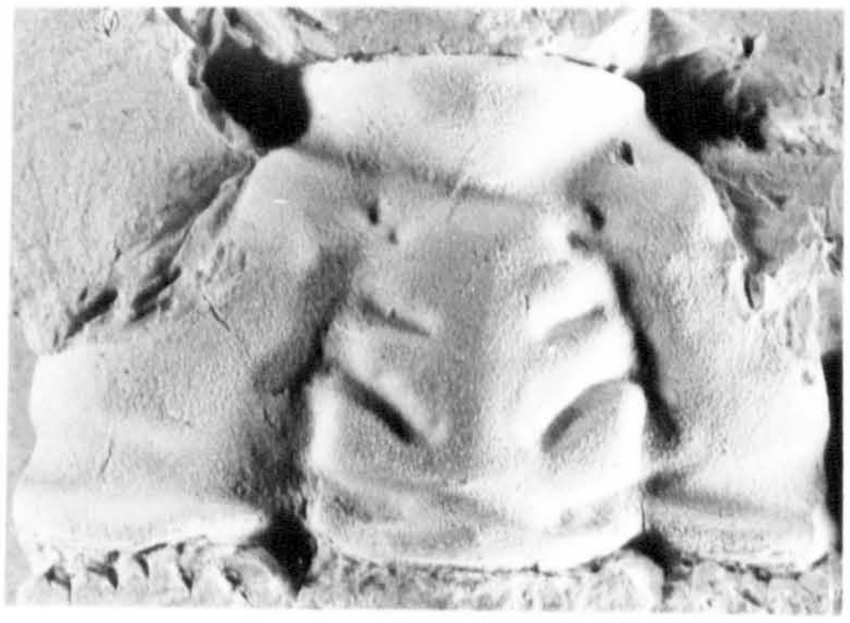

10a

10b


5c

b. Graptolites

The graptolites described here only represent three geological series Llanvirn, Caradoc and Llandovery. They are as follows:

Didymograptus bifidus (Hall, 1865)

Glyptograptus (G.) incertus (Elles and Wood, 1907)

Climograptus cf. normalis Lapworth, 1877

Monograptus cf. convolutus (Hisinger, 1837)

Monograptus cf. decipiens decipiens Törnquist, 1899

Monograptus cf. lobiferus (McCoy, 1850)

Monograptus sp.

Pristiograptus regularis regularis (Törnquist, 1899)

Pristiograptus cf. nudus (Lapworth, 1880)

Lagarograptus tenuis (Portlock, 1843)

Petalograptus ovatoelongatus Kurck, 1882)

Petalograptus minor Elles, 1897

Method of study:-

In the description of the graptolites below, the terms are essentially those defined in the 'Treatise on Invertebrate Palaeontology,' part V, (Bulman, 1970). The term thecal spacing is used here in the sense applied by Packham (1962), and Rickards (1965) the term geniculum of Jaanusson (1960) is employed and thecal length (Rickards, 1965) is used in this study. Since no isolated specimens of the graptolites under investigation are available, descriptions thus depend solely upon external morphology. Measurements have been done by means of a binocular microscope with a graticule eye-piece at magnification of x 6, and x 12.

Systematic description:-

Classification of the graptolites applied in this study is mainly based on the 'Treatise on Invertebrate Paleontology', part V, Graptolithina, (Bulman, 1970).

Class GRAPTOLITHINA Bronn, 1846

Order GRAPTOLOIDAE Lapworth, 1875

Suborder DIDYMOGRAPTINA Lapworth, 1880, (emend. Bulman, 1970)

Family DICHOGRAPTIDAE Lapworth, 1873

Pauciramous forms:-

Pendent, deflexed, declined, horizontal, reflexed, reclined or scandent, wholly or in part; branching dichotomous to first or second order only; thecae simple, rarely with sigmoidal curvature or elaborated apertural modifications.

Section DIDYMOGRAPTI

Pendent to scandent, composed of not more than two stipes.

Genus DIDYMOGRAPTUS McCoy, 1851

Type species:- Graptolithus murchisoni Beck, 1839, p.9.

Diagnosis:- (from Bulman 1970, V116)

Pendent to reclined; development of dichograptid or isograptid type; thecae typically simple, straight or with slight ventral curvature.

Didymograptus bifidus (Hall, 1865)
Pl. 3, figs. 4,6; Text-fig. 3a-c

1865 Graptolithus bifidus Hall (pars); 73-74; pl.1, figs.16-18; non pl.3, figs. 9,10.

1904 Didymograptus bifidus (Hall); Ruedemann; pp. 689-692, pl.15, fig. 1-3.

1962 Didymograptus bifidus (Hall); Berry; pp. 294-297, text-fig. 1a-d.

1970 Didymograptus bifidus (Hall); Berry; pp.64-65, figs.1b,c,f, 2c.

1976 Didymograptus bifidus (J. Hall, 1865); Fortey; pp. 274-275 text-fig.3.

Lectotype:

Subsequently designated by Berry 1962, pp.294-298, text-fig. 1a-d,2a,b.

Material:-

More than 10 specimens, preserved in flattend.

Locality and horizon:-

Al-Bukayria, Al-Qassim, D. bifidus Zone, Llanvirn.

Description:-

The stipes diverge initially at 90° -101°, then curving round so as to include an angle of 20°-25°. They are 0.7 mm wide proximally but they widen gradually to 1.2-1.3 mm at 5 mm and 2.1 mm distally. The siculae are conspicuous, slender, and approximately 1.4-1.6 mm in length. The first theca th.1 originates slightly above the sicula aperture 0.75 mm. The thecae are long, slender, and slightly curved tubes; they count about 15 in 10 mm; they are three times as long as wide, and free about half of their length. The thecae inclined initially at an angle of 30°-45° to the stipe axis. The thecae on one stipe appear to be at about the same level of the other stipe. The apertural margins are slightly concave, and some specimens show a slight excavations.

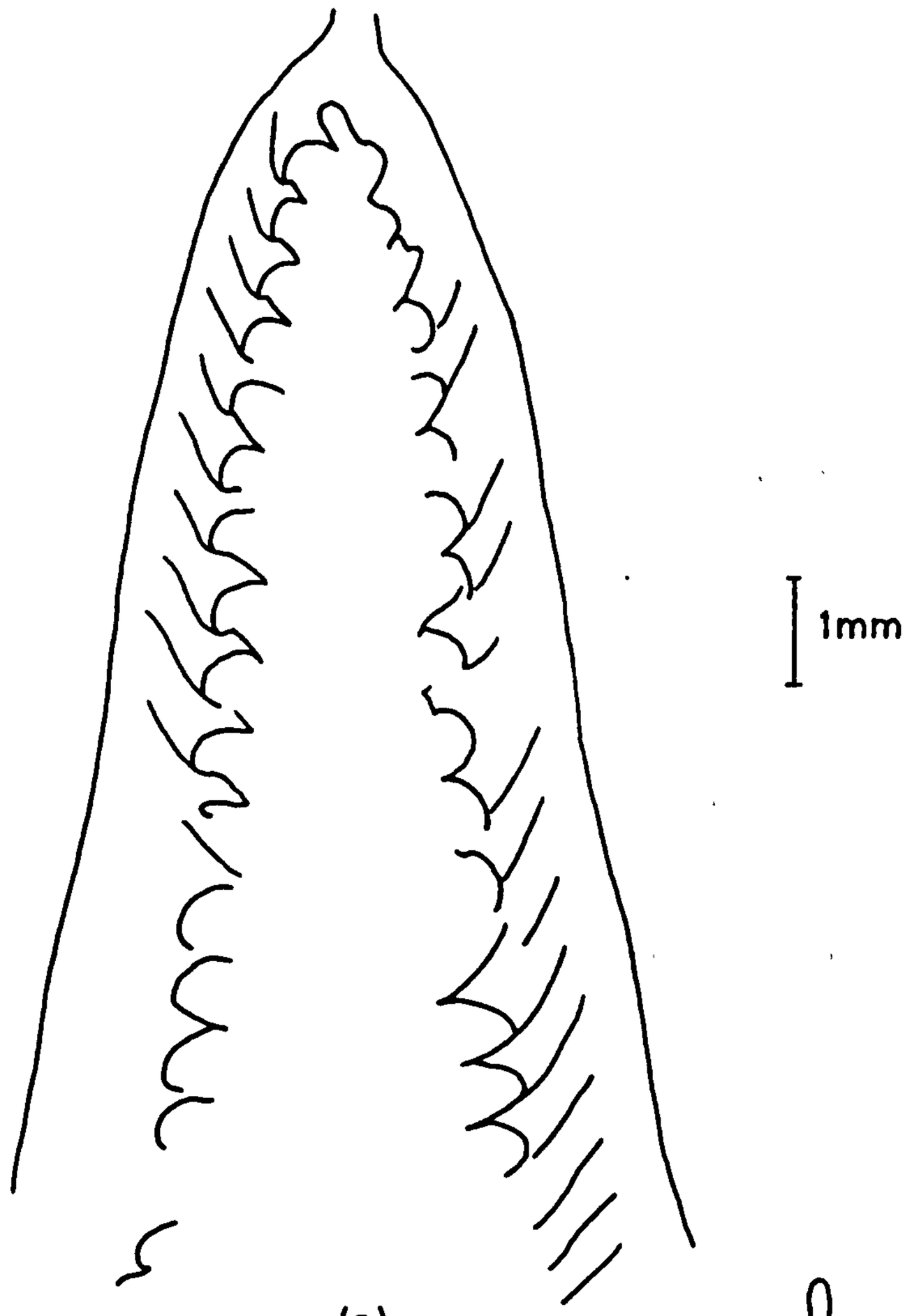
Remarks:-

Didymograptus bifidus resembles D. Murchisoni var. gemminus (Hisinger) in its general shape, but distinguished by thecal number is more than D. murchisoni var. gemminus; the sicula of D. murchisoni var. gemminus is higher in length about 2.6 mm. D. bifidus also differs from D. protobifidus Elles by the width of the stipe is greater in D. bifidus; the sicula is less in length, thecal spacing more closed than that of D. protobifidus, and the divergence of the stipes is wider in D. bifidus.

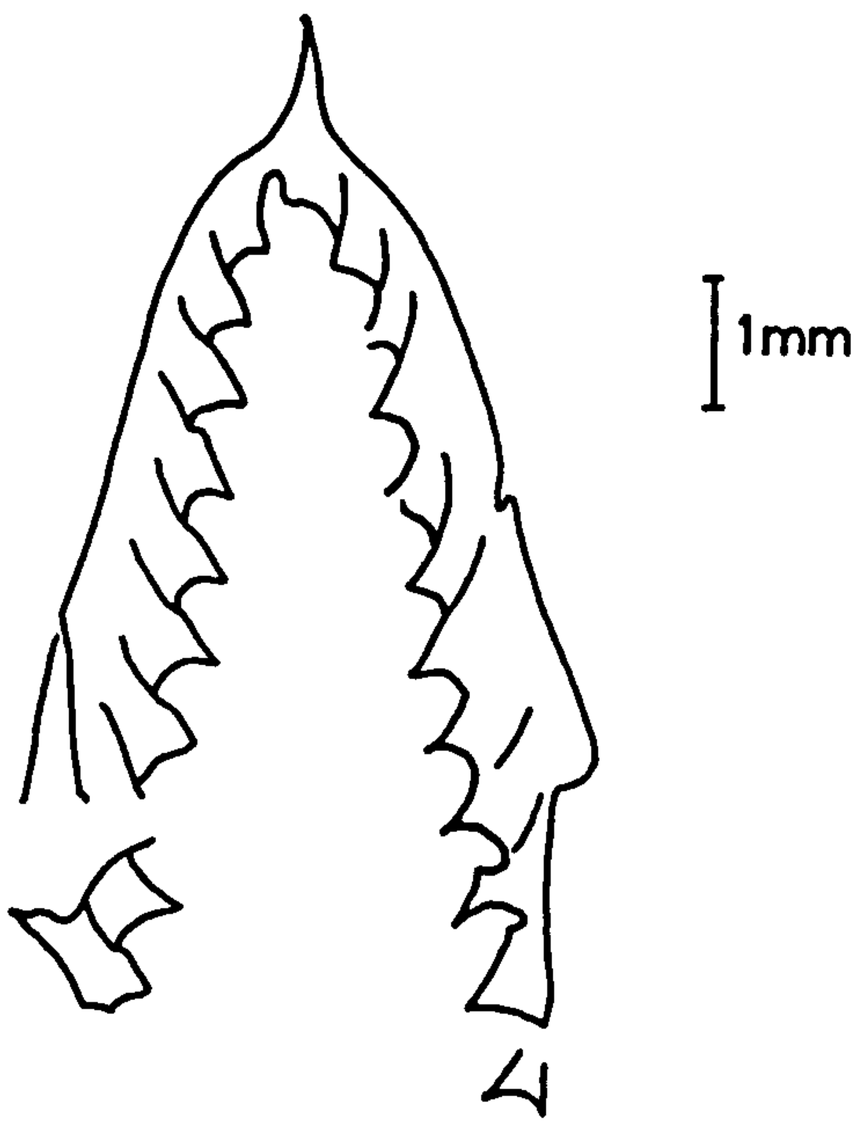
Text-fig. 3 a- Didymograptus bidifus (Hall), BD 210, D. bifidus Zone, loc Al-Bukayriah.

b- Didymograptus bifidus (Hall),BD 10 (2), D. bifidus Zone, loc. Al-Bukayriah.

c- Didymograptus bifidus (Hall),BDT (1) D. bifidus Zone, loc. Al-Bukayriah.



(a)



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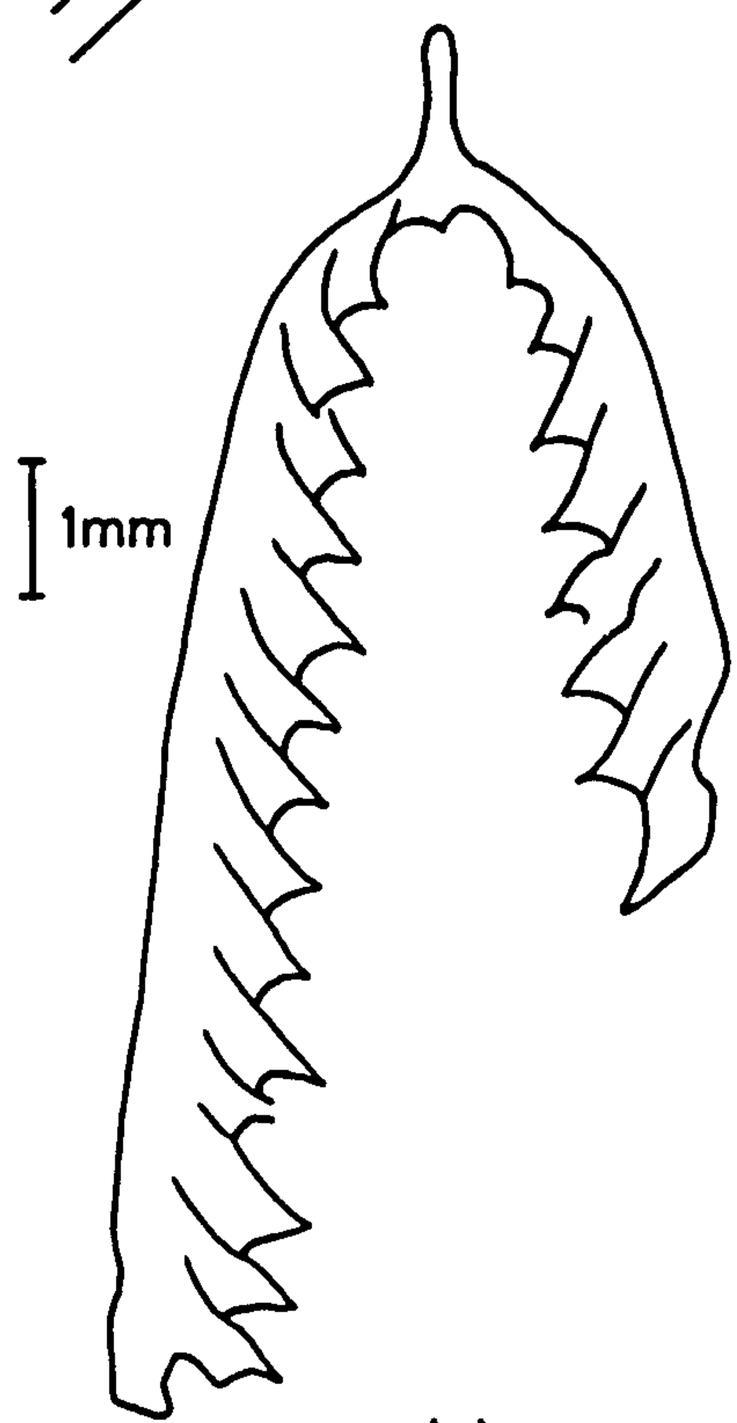


(c)

Suborder DIPLOGRAPTINA Lapworth, 1880 (emend. Bulman, 1970)

Family DIPLOGRAPTIDAE Lapworth, 1873

Genus GLYPTOGRAPTUS Lapworth, 1873

Type species:- Original designation; Diplograptus tamariscus Nicholson, 1868, p.526, pl.19, figs.10-13; from Duffkinnel, near Wamphray, Southern Scotland.

Diagnosis:- Hutt, 1974, pp. 23-24

Thecae with gentle sigmoidal curvature; supragenicular wall almost straight, sloping outwards, or rarely with gentle double curvature; apertural margins horizontal, undulate or everted; rhabdosomal cross-section ovoid or nearly circular.

Subgenus Glyptograptus (Glyptograptus)

Lapworth, 1873

(= Comograptus Obut, Soblevskaya (& Merkureva), 1968; ?Agetograptus (pars) Obut, Soblevskaya (& Merkureva), 1968; Hedrograptus Obut, 1949 (pars))

Type species:- Original designation; Diplograptus tamariscus Nicholson, 1868, p.526, pl.19, figs.10-13; from the Llandovery of Scotland.

Diagnosis:- Bulman & Rickards, 1968.

Thecae with gentle sigmoidal curvature, apertural margins commonly undulate.

Glyptograptus (G.) incertus (Elles & Wood, 1907)
Pl. 3, fig. 5, Pl. 4, figs. 5-6; Text-figs. 4a-c.

1907 Diplograptus (Glyptograptus) tamariscus Var. nov.; Elles & Wood, p.249, pl.30, figs.9a-d, text-figs.168a,b.

1962 Glyptograptus incertus Elles & Wood; Packham, p.518, pl.72, figs.6,7, text-figs.4a-d.

1970 Glyptograptus aff. incertus (Elles & Wood, 1907); Rickards, p.40, text-fig.14, fig.11.

1974 Glyptograptus (G.) incertus (Elles & Wood, 1907); Hutt, p.25, pl.3, fig.3, pl.4, figs.12,13, text-fig.8, fig.11.

Lectotype:-

Subsequently designated Packham 1962, p.518; figured Elles & Wood 1907, pl.30, fig.9c; BU1274; from the Birkhill Shales (Llandovery) of Graple Linn, Moffat, Scotland.

Material:-

Over 10 specimens, mostly flattened and some in low relief.

Locality and horizon:-

AlMadbaa, AlQassim, Caradoc Series, Tabuk Formation.

Description:-

The rhabdosome is long, reaching a length of 25 mm, and parallel-sided for much of its length. The rhabdosome width increased gradually, at the level of th.1 is about 1 mm, to about 1.8 mm at the level of th.5, and reaching 2.25 mm as a maximum width. The length of sicula is about 1.55 mm, and its apex extending fractionally above th.2. Some specimens exhibit the median septa. The sigmoidal curvature of the thecae varies throughout the rhabdosome; the proximal thecae are strongly

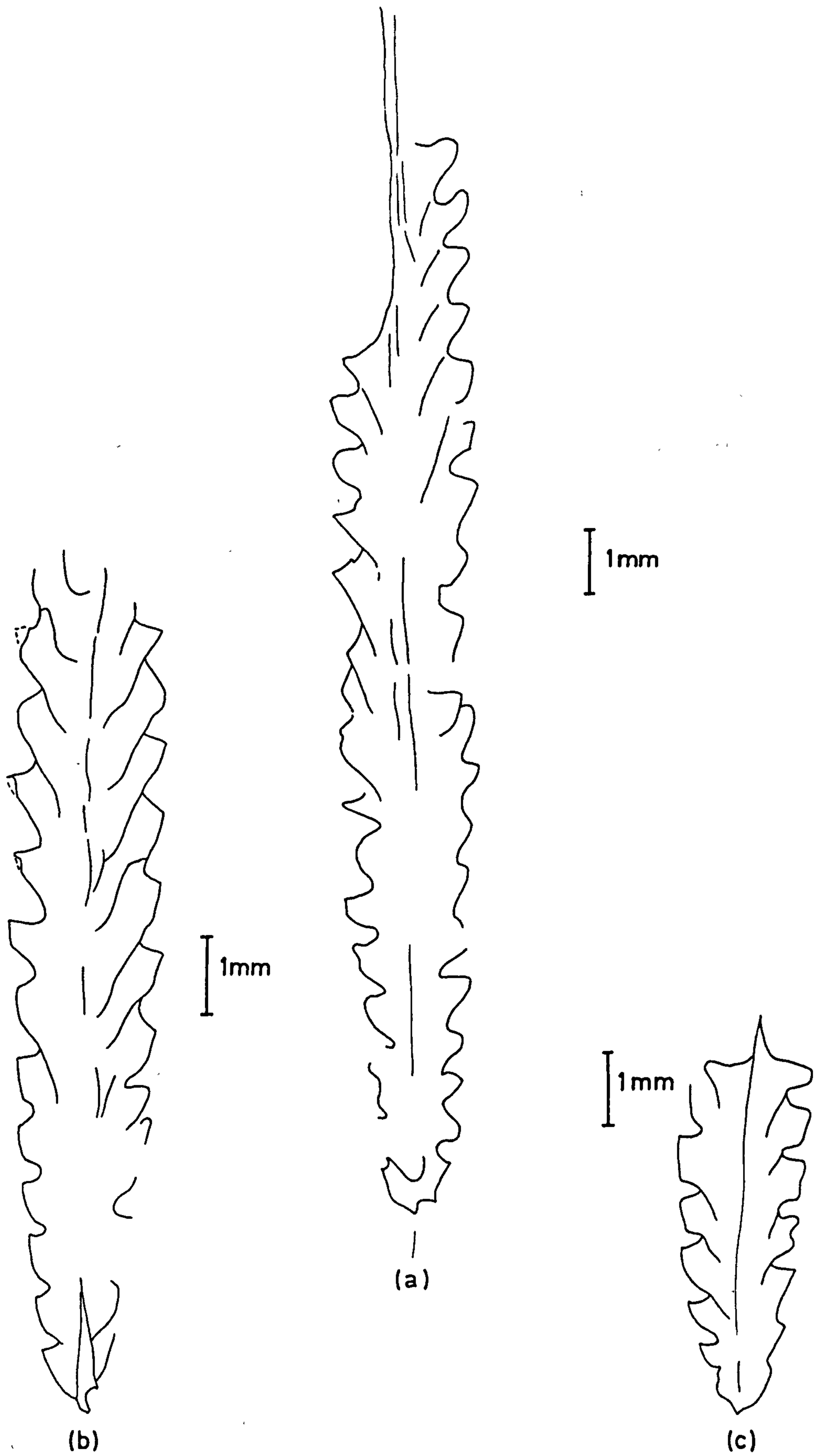
Specimen Number	Flat or relief	Length of rhabdosome	Width			Length		Sicula	Number of th. per 10 mm
			th.1	th.5	Max-imum	th.1[1]	th.1[2]		
ITR081 (4)	F	over 5.4	1.0	1.85	-	0.75	0.85	-	13
ITR081 (2)	F	over 5.4	1.0	1.8	-	0.7	0.8	-	13
ITR082 (1)	F,L.r	over 21.0	1.1	1.9	2.3		≈0.6	≈1.5	13
ITR083 (1)	F,L.r	over 25.0	1.0	≈1.8	2.0	0.7	≈0.8	?1.3	13
ITR083 (2)	F	very short	1.05			0.7	0.9	≈1.0	14
ITR084 (2)	F	very short	1.05			0.8	1.0	≈1.3	13
ITR084 (1)	F	16.0		1.8	2.3	-	-	-	14
ITR085 (1)	F	17.8	1.05	1.8	2.5	0.8	0.85	-	13
ITR087 (1)	F	short	1.0		1.4 at th.3	0.8	0.85	1.55	≈14

Table 2 Recorded specimens of Glyptograptus (G.) incertus Dimensions (in millimetres)

Text-fig. 4 a- Glyptograptus (G.) incertus (Elles & Wood), ITR085a(1), loc. Al-Madbaa.

b- Glyptograptus (G.) incertus (Elles & Wood), ITE081(2), loc. Al-Madbaa.

c- Glyptograptus (G.) incertus (Elles & Wood), ITE087(1), loc. Al-Madbaa.


1mm
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(a)
(b)
(c)

sigmoidal but become less sigmoidal distally. The excavations are deep, slightly everted margin, and widening distally. The thecae overlap for about half of their length. The thecal spacing count 13-14 in 10 mm. The proximal end is broad with short virgilla.

Remarks:-

G. incertus from AlMadbaa, Caradoc Series, agrees with the description of the Llandoverian G. incertus of the previous authors; the Llandoverian taxa differ in being narrower than that of the Caradocian. In AlMadbaa Monograptus has not been found, associated with G. incertus.

Genus CLIMACOGRAPTUS Hall, 1865

[= Paraclimacograptus Přibyl, 1947; Hedrograptus Obut, 1949]

Type species:- Original designation; Graptolithus bicornis Hall, 1847, p.268, pl.73, fig.2; from the Upper Ordovician of New York State, U.S.A.

Diagnosis:- Bulman 1970, (V125)

Rhabdosome nearly circular in cross section, scalari form views consequently common; thecae strongly geniculate, with deep apertural excavations, supragenicular wall straight, parallel to axis of rhabdosome.

Climacograptus cf. normalis Lapworth, 1877.
Pl. 3, figs. 1-2, 9; Text-fig. 5a-c.

1877 Climacograptus scalaris var. normalis; Lapworth, p.138, pl.6, fig.31.

1906 Climacograptus scalaris (Hisinger) var. normalis, Lapworth; Elles & Wood, p.186 pl.26, figs.2a-g, text-figs. 119a-d.

1970 Climacograptus normalis Lapworth, 1877; Rickards, p.28, pl.1, figs.1,7,8, text-fig.13, figs.7,8.

1974 Climacograptus normalis Lapworth, 1877; Hutt, pp.19,20, pl.1, figs.8,9, pl.2, figs.1,2,3?,4.

Material:-

Over 10 specimens, flattened and some in low relief.

Locality and horizon:-

Jabal Antar, Qusayba, Al-Qassim, convolutus Zone, Llandovery Series.

Description:-

The rhabdosome is sub-paralell for most of its length. The proximal end is round with conspicuous and short virgella. A complete sicula has not been seen. The increase in the width of rhabdosome is gradual, 0.8-0.9 mm at th.1, 1.25-1.3 mm at th.5, and reaching maximum width of 1.4, 1.6? mm. The thecal spacing is 10-12 in 10 mm proximally. The free edge of the thecae are straight with abrupt genicula, and apertural margins are horizontal. Thecal excavations are typical kind of climacograptid, deep, semicircular, and may occupy about one-third of the rhabdosome width.

Remarks:-

C. cf. normalis specimens from Al-Qassim agree with the previous description of C. normalis except in their rhabdosome length, the latter has longer length. C. cf. normalis resembles C. minimus (Carruthers) Elles & Wood, and C. brevis Elles & Wood in general features but are different in the size of the rhabdosome width. C. minimus has a bigger size, and attains its maximum width 2 mm at 4 mm; C. cf. minimus has only 1.3-1.5 mm as a maximum width at 4 mm. C. brevis has a smaller size than C. cf. normalis about 1 mm; also C. brevis thecal spacing counts more than that of C. cf. normalis.

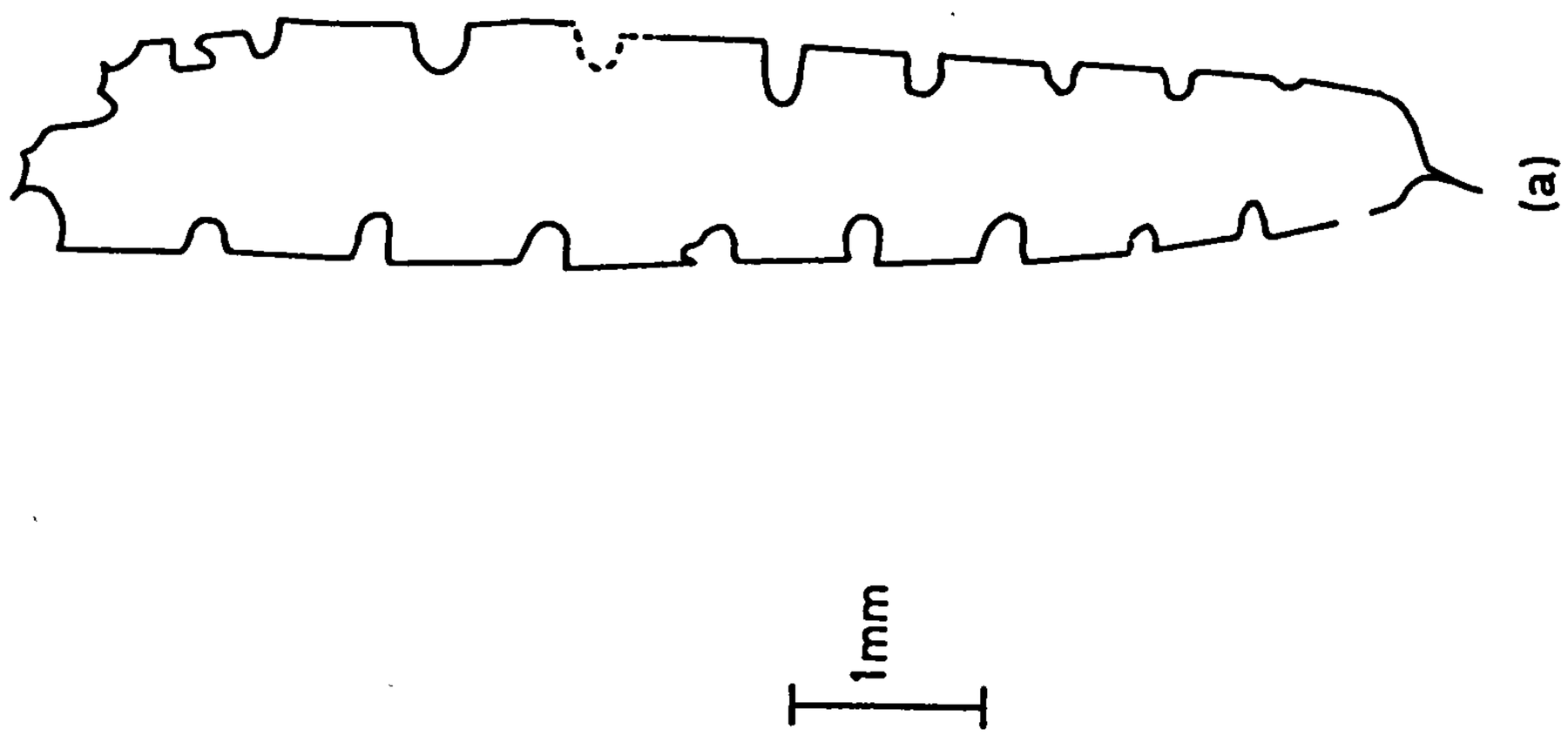
Specimen Number	Flat or relief	Length of rhabdosome	Width th.1	Width th.5	Width Maximum	Sicula	Number of th. per 10 mm	Notes
q_m 091 a,b	F	8.1	0.9	1.3	1.4	not observed	11 - 12	short virgella = 0.35
q_1AB (1)	L.r.	10.6	0.85	1.25	1.3 ?	not observed	11 - 12	short virgella
q_m 092 (1)	L.r.	14.0		≈1.3	1.6	not observed	10 - 11	subscalariform
q_3 12_a (1)	F	11.2	0.8	1.25	1.4	not observed	12	subscalariform,very short virgella
q_3 12_a (3)	F	12.4	0.8	1.3	1.4	not observed	10 - 11	subscalariform,very short virgella
q_m 092 (2)	L.r.	10.00	0.85	1.25	1.4	not observed	12	scalariform

Table 3. Recorded specimens of Climacograptus cf. normalis. Dimensions (in millimetres).

Text-fig. 5 a- Climacograptus cf. normalis Lapworth, $q_1$091a, convolutus Zone, loc. Jabal Antar, Qusayba.

b- Climacograptus cf. normalis Lapworth, $q_1$026, convolutus Zone, loc. Jabal Antar, Qusayba.

c- Climacograptus cf. normlis Lapworth, q_1AB(1), convolutus Zone, loc. Jabal Antar, Qusayba.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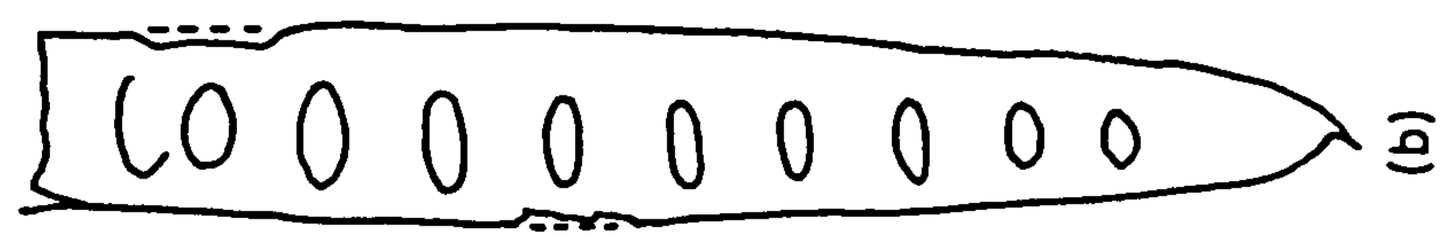
(b)
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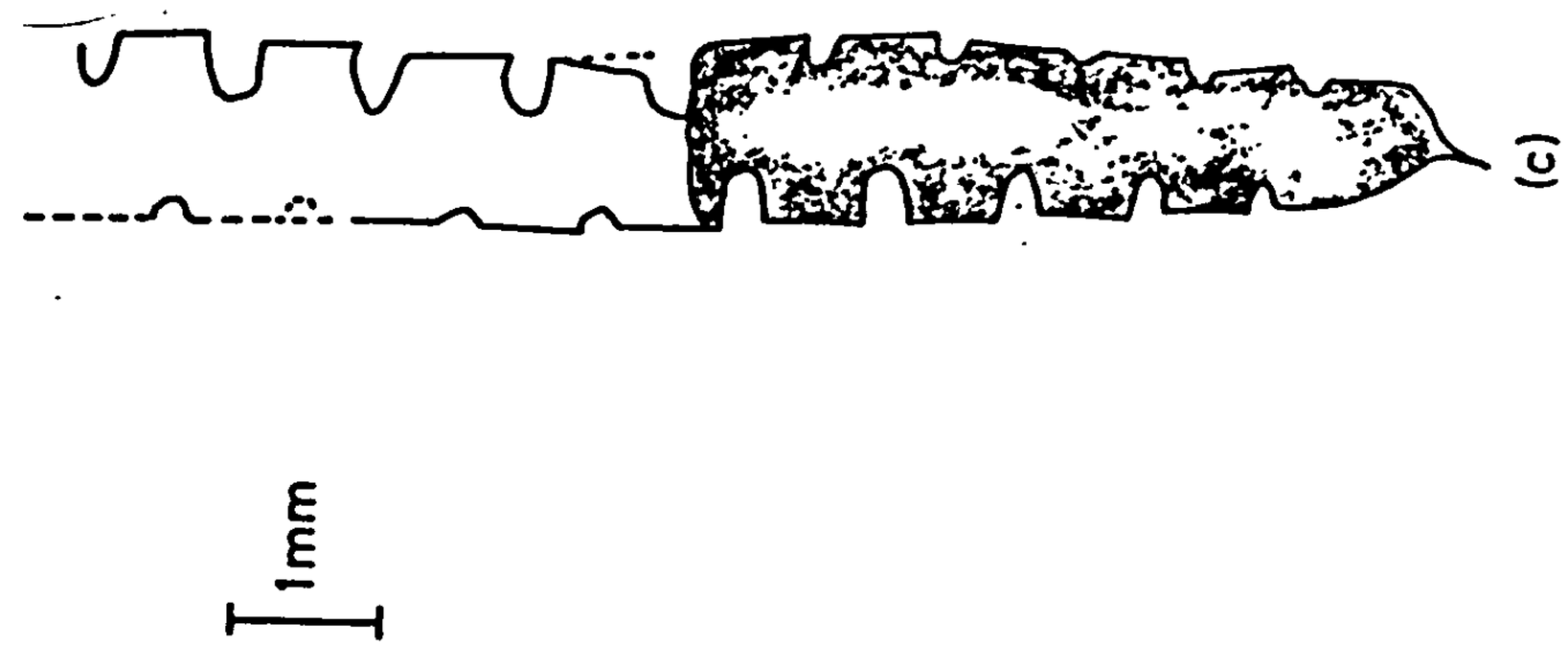

(c)
1mm

Genus MONOGRAPTUS Geinitz, 1852 (emend. Hutt, 1975)

(pro Lomatoceras Bronn, 1835; Monoprion Barrande, 1850; ICZN opinion 198) (= Pomatograptus Jaekel, 1889; Spirograptus Gürich, 1908; Demirastrites Eisel, 1912; Oktavites Levina, 1928; Streptograptus Yin, 1937; Pernerograptus Přibyl, 1942; Colonograptus Přibyl, 1943; Mediograptus Bouček & Přibyl, 1948; Globosograptus Bouček & Přibyl, 1948; Tyrsograptus Obut, 1949 (=Spirograptus); Campograptus Obut, 1949; Obutograptus Mu, 1955 (=Oktavites)).

Type species: Subsequent designation Bassler 1915, p.822; Lomatoceras priodon Bronn, 1835, p.56, pl.1, fig.13; from the Silurian of Germany.

Monograptus cf. convolutus (Hisinger, 1837)
Pl. 4, figs. 1, 4; Text-figs. 6a-b.

1837 Prionotus convolutus Hisinger, p.114, pl.35, fig.7.

1868 Graptolithus convolutus Hisinger; Carruthers, pl.5, fig.1a (?b,c).

1913 Monograptus convolutus (Hisinger); Elles & Wood, pp.467-9, text-figs.324 a-b, pl.47, figs.1a-d.

1958 Monograptus convolutus (Hisinger); Sudbury, pp.511-3, text-fig.13, pl.21, figs.76-78.

1970 Monograptus convolutus (Hisinger, 1837); Rickards, pp.82-3, text-fig.13, fig.15.

1975 Monograptus convolutus (Hisinger, 1837); Hutt pp.83-4 text-fig.22, fig.2,6, pl.19, fig.3, pl.25, fig.3.

Holotype: By monotypy; figured Hisinger, 1837, pl.35, fig.7 and Tullberg, 1882, pl.2, fig.13; from the Diplograptus cometa Zone of furudal, Sweden.

Locality and horizon:-

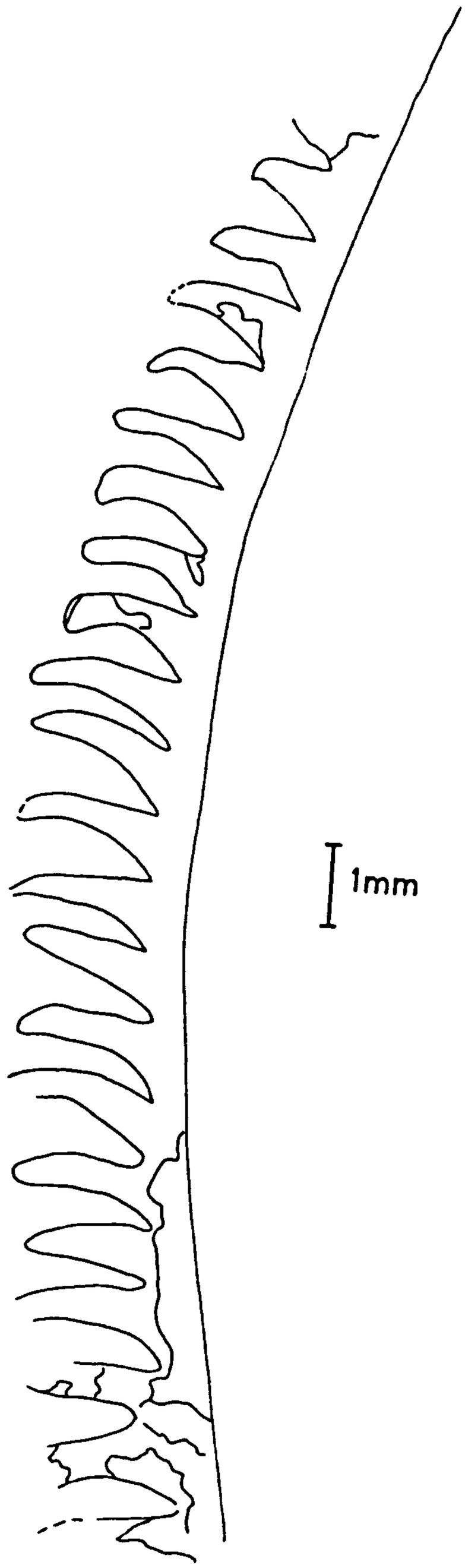
Jabal Antar, Qusayba, Al-Qassim, convolutus Zone, Llandovery Series.

Description:-

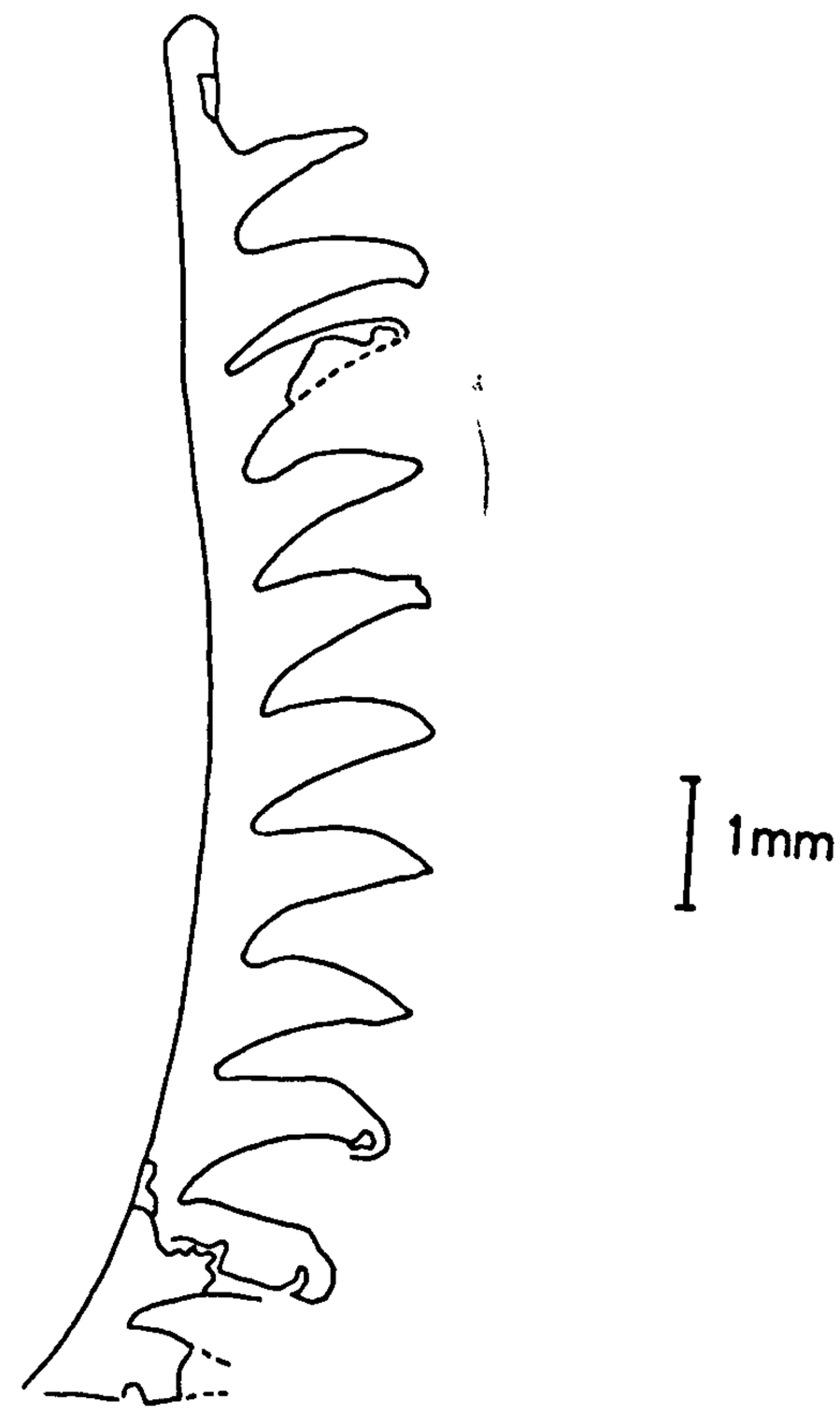
Most fragments found are of the distal parts and show dorsal curvature. Thecae are situated on the convex side, without overlap. Distal thecae are usually 2.0-3.0 mm in height. The thecae are long, narrow, and transversely elongated at the aperture. The apertural region is gently curved, forming a slight hook. The thecal

Text-fig. 6 a- Monograptus cf. convolutus (Hisinger), $Q_3$1a(1), convolutus Zone, loc. Jabal Antar, Qusayba.

b- Monogaptus cf. convolutus (Hisinger), $q_3$14b(2), convolutus Zone, loc Jabal Antar, Qusayba.



(a)



(b)

spacing is 7½-9 per 10 mm.

Remarks:-

Monograptus cf. convolutus agree with the description of Sudbury (1958). Sudbury (1958) distinguished between M. convolutus and M. triangulatus triangulatus (Harkness) that M. convolutus usually are greater thecae height than M. triangulatus triangulatus. Here it has been used the same differentiation.

Material:-

Over ten flattened specimens.

Monograptus cf. decipiens decipiens Törnquist, 1899
Pl. 5, fig. 5; Text-fig. 7a.

1899 Monograptus decipiens n.sp.; Törnquist, p.20,pl.4, figs.9-4.

1913 Monograptus decipiens Törnquist; Elles & Wood, p. 469 (pars), pl.47, figs.3a,b,e (non c,d), text-fig.325a.

1958 Monograptus decipiens Törnquist; Sudbury, pp.510-11, pl.21, figs. 74,75.

1970 Monograptus decipiens Törnquist, 1899; Rickards, p.83, text-fig.13, fig.16, text-fig.17, fig.8, text-fig.18, figs.3,13.

1975 Monograptus decipiens decipiens, 1899; Hutt, pp. 85-86, text-fig.17, fig.5, text-fig. 20, pl.21, figs.2-4.

Lectotype subsequently designated by Přibyl and Münch, 1942, p.12: specimen figured Törnquist, 1899, pl.4, fig.10; from the convolutus Zone, Sweden.

Material:-

One well preserved proximal end.

Locality and horizon:-

Jabal Antar, Qusayba, Al-Qassim, convolutus Zone, Llandovery Series.

Description:-

The rhabdosome is coiled dorsally curved. The sicula is slender just below the base of metatheca of th.1. The thecae are located on convex margin of the rhabdosome and the first

seven or eight thecae are rastritiform. Thecal spacing is 10 in 10 mm proximally. The width of the metatheca proximally is about 0.1 mm narrowing (in profile) towards the aperture. The dorso-ventral width of protheca is about 0.8 mm (inflattend). The metatheca height is 0.6 mm at th.1 and gradually increases to about 0.9 mm at th.7, and separate each other by long prothecae. The thecae terminate in a small hooked aperture.

Remarks:-

All the characters of this specimen agree with previous descriptions of the proximal end of this species. Moreover, in the absence of the distal end of M. decipiens decipiens it is probable that M. cf. decipiens decipiens will be included within this taxon until further material is available.

Monograptus cf. lobiferus (McCoy, 1850)
Pl. 5, figs. 2-3; Text-fig. 7b.

1850 Graptolites lobiferus (McCoy); McCoy, p.270.

1876 Monograptus lobiferus (McCoy, sp.; Lapworth), p.499, pl.20, figs.1a,b and d (non figs. c and e).

1913 Monograptus lobiferus (McCoy); Elles & Wood, p.448, pl.45, figs. 1a-f, text-figs.308a-e.

1970 Monograptus lobiferus (McCoy); Churkin & Carter, p.42, pl.3, figs.12,21.

1975 Monograptus lobiferus (McCoy, 1850); Hutt , pp. 94-5, pl.18, figs.1,3,pl.19, fig.6, text-fig.24, fig.4a,b.

Holotype: SMA21182; figured McCoy 1855, pl.1B, fig.3; refigured Elles & Wood 1913, pl.45, fig.1a; from the Birkhill Shale of Moffat, Scotland.

Material:-

Three flattened specimens.

Locality and horizon:-

Jabal Antar, Qusayba, Al-Qassim, convolutus Zone, Llandovery.

Text-fig. 7 a- Monograptus cf. decipiens decipiens Törnquist

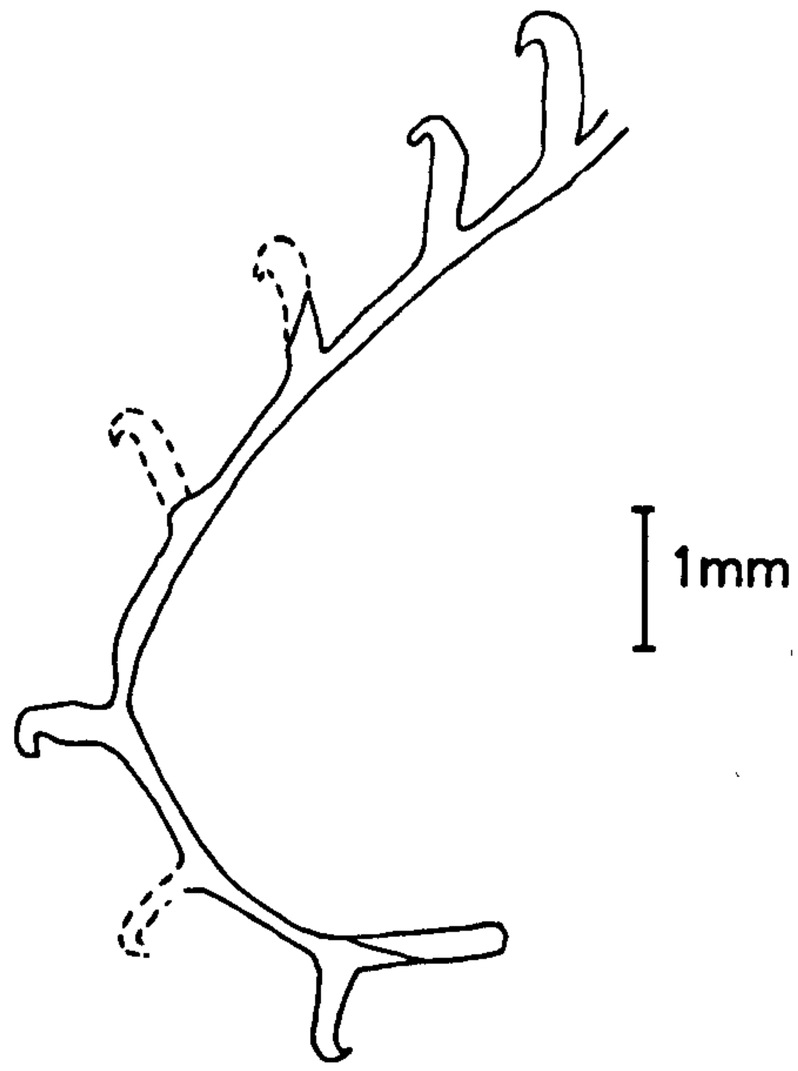
$q_1$019a(1), proximal end, convolutus Zone, loc. Jabal Antar, Qusayba.

b- Monograptus cf. lobiferus (McCoy),

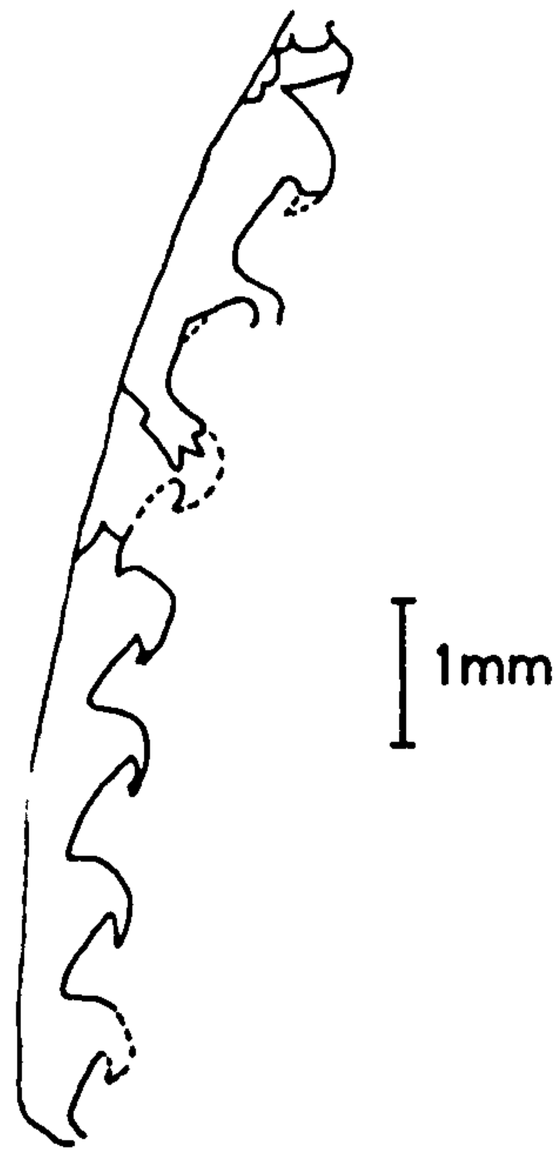
$q_5$1a(1), convolutus Zone, loc. Jabal Antar, Qusayba.

c- Monograptus sp.

$q_3$14b(1), convolutus Zone, loc. Jabal Antar, Qusayba.



(a)



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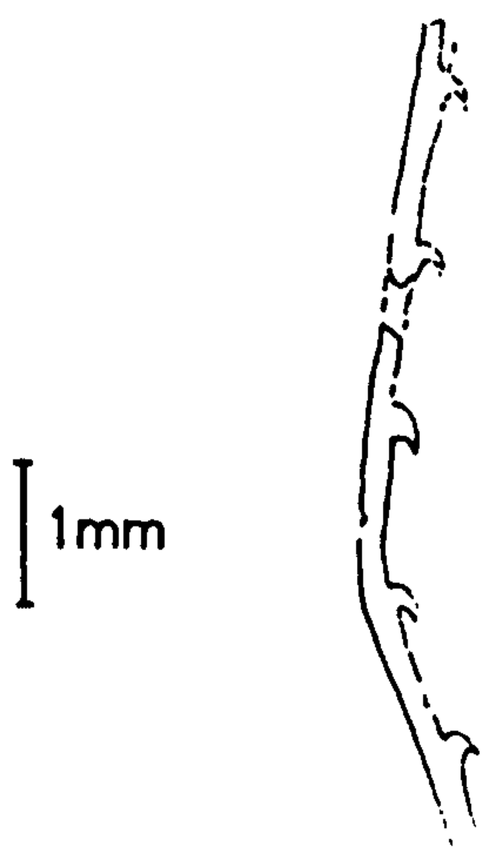


(c)

Description:-

The rhabdosomes show different curvatures, and thecae are situated on the concave side. The thecae are of one type throughout the rhabdosome, and they are strongly hooked with the lobe accounting for half of total dorso-ventral width of the rhabdosome. The dorso-ventral width is 0.65-0.9 mm, and thecal spacing is 10-9 in 10 mm.

Monograptus sp.

Pl. 5 , fig. 8 , Text-fig. 7c

Material:-

One incomplete flattened specimen.

Locality and horizon:-

Jabal Antar, Qusayba, Al-Qassim, convolutus Zone, Llandovery Series, Tabuk Formation.

Description:-

The rhabdosome shows dorsal curvature. The thecae are widly spaced about eight in 10 mm. They are closely adpressed to the rhabdosome axis, the aperture at the extreme distal end of the thecae shows a small prominent hook. The hook occupies about one-quarter of the rhabdosome width. There is no thecal overlap. The prothecal portion appears as a flattend form of a slender tube but is slightly wider at at the upper part. The width of the rhabdosome is 0.4 mm.

Remarks:-

The Monograptus sp. is in general similar to Monograptus simulatus Rickards(1965), but differs in the theacal spacing which the

latter has more widely spaced, and the rhabdosome is slightly narrower. Also Monograptus sp. generally is similar to Monograptus crinitus Wood (1900) but the latter has a slight overlap, and the thecal spacing closely spaced.

Insufficient material makes it difficult to assign this specimen to any of the above species.

Genus PRISTIOGRAPTUS Jaekel, 1889

Type species:- Original designation; P. frequens Jaekel, 1889, p.669, pl.28, figs. 1,2; from the Silurian of Germany.

Diagnosis:- Hutt, 1975

Rhabdosome straight or with slight ventral curvature. Thecae simple, cylindrical with straight or slightly ventrally curved free ventral walls and without any distinctive apertural processes.

Pristiograptus regularis regularis (Törnquist, 1899). Pl. 4, figs. 2-3, 7; Text-figs.8a-b.

1899 Monograptus regularis n. sp.; Törnquist, p.7, pl.1, figs. 9-14.

1911 Monograptus regularis Törnquist; Elles and Wood, pp.372-3, text-figs. 243, a-c, pl.37, figs. 3a-d.

1970 Pristiograptus regularis regularis; Törnquist, 1899; Rickards p.59, pl.5, fig.4, text-fig. 16, fig.16.

1974 Monograptus regularis Törnquist, 1899; Sherwin, p.157, pl.11, fig.10, text-fig. 2e.

1975 Pristiograptus regularis regularis (Törnquist, 1899); Hutt, pp.58-9, pl.11, fig.10, pl.12, fig.4; text-fig.14,fig.7.

Lectotype: Tornquist syntypes from the Llandovery of Sweden.

Material:-

More than ten flattened specimens.

Locality and Horizon:-

Jabal Antar, Qusayba, Al-Qassim, convolutus Zone, Llandovery Series, Tabuk Formation.

Description:-

The rhabdosome is generally straight throughout. The proximal end is rather slender and bears a tiny sicula about 0.7 mm in length. The sicula apex reaches to the level of aperture of th.1. The dorso-ventral width at th.1 is about 0.2 - 0.25 mm. The dorso-ventral width of the rhabdosome increases rapidly over the first few thecae, at 1 cm the dorso-ventral width is 0.5 - 0.6 mm, at 2 cm is 0.7 - 0.75 mm, at 3 cm is 0.9 - 0.95 mm. The proximal thecae are closely spaced and thecae count 11½-12½ in 10 mm proximally and the number decreases quickly to 10-11 in 10 mm distally. The thecae are simple tubes which show a slight expansion of the free ventral wall. They are inclined at 20° to the rhabdosome axis proximally, and the thecae overlap to less than half proximally but more distally. The thecae show a slight excavation.

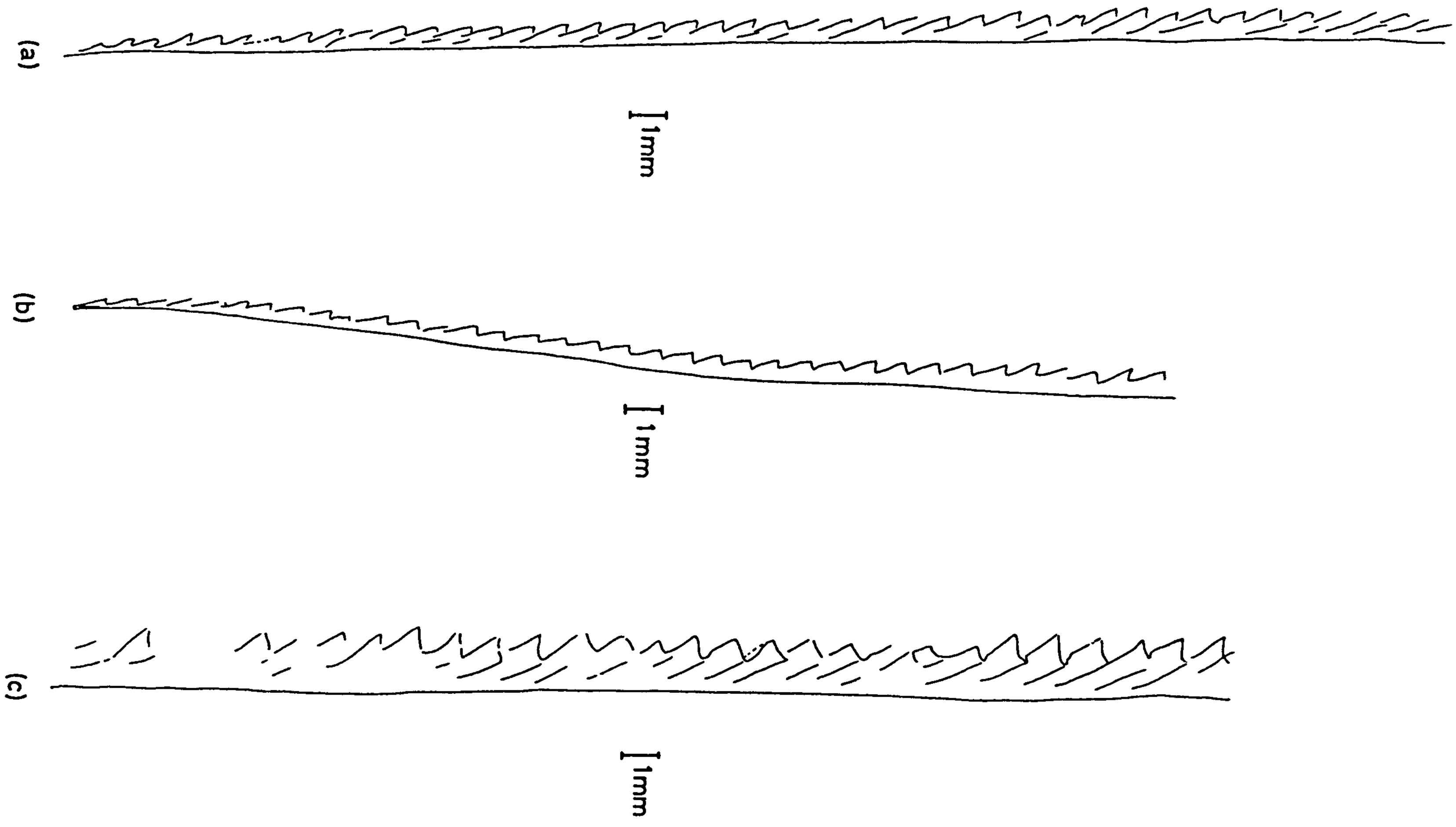
Remarks:-

Rickards (1970) found rare specimens occuring questionably in the sedgwickii Zone at Howgill Fells; these are small and have the thecae more closely spaced (15 in 10 mm) and the dorso-ventral width is 0.26 mm at the level of th.1. Comparison with specimens from Al-Qassim shows that the dorso-ventral width at the level of th.1 are the same, but less closely spaced (11½-12½ in 10 mm).

Text-fig. 8 a- Pristiograptus regularis regularis (Törnquist), $q_3$5b, convolutus Zone, loc. Jabal Antar, Qusayba.

b- Pristiograptus regularis regularis (Törnquist), $q_5$5(1), convolutus Zone, loc. Jabal Antar, Qusayba.

c- Pristiograptus cf. nudus (Lapworth), $q_5$4a(1), convolutus Zone, loc. Jabal Antar, Qusayba.


(a)
1mm
(b)
1mm
(c)
1mm

Pristiograptus cf. nudus (Lapworth, 1880)
Pl. 4, fig. 8; Text-fig. 8c

1876 Monograptus Hisingeri, Carr, sp.; Lapworth, p.350, pl.12, figs.1a,b,d,e,?f.

1880 Monograptus Hisingeri, Carr. var. nudus var. nov.; Lapworth, p.156, pl.4, figs.7a-c.

1911 Monograptus nudus (Lapworth); Elles & Wood, p.375, pl.37, figs. 6a-e, text-figs.246a-d.

1970 Pristiograptus nudus (Lapworth, 1880); Rickards, p.59, pl.7, fig.1.

1975 Pristiograptus nudus (Lapworth, 1880); Hutt, p.59, pl.11, figs.5,6.

Lectotype: Designated Přibyl, 1948, p.74; figured Lapworth, 1876, pl.12, fig.1a; BU 1461; from the Llandovery of Grieston Quarry, Peeblesshire, Scotland.

Material:-

Two flattened specimens of distal ends.

Locality and horizon:-

Jabal Antar, Qusayba, Al-Qassim, convolutus Zone, Llandovery Series

Description:-

The rhabdosome is straight and long. A distal fragment is over 4 cm long. Thecae are simple tubes, count 10 in 10 mm and maintain throughout 4 cm of the distal portion. The thecae are inclined at 30°-40° to the rhabdosome axis. The thecal length reaches about 2-2.2 mm, and the overlap is approximately one-half of the length. The free ventral margin of each theca is somewhat impressed, producing a slight excavation.

Remarks:-

The Al-Qassim specimens agree with the description of P. nudus

by Rickards (1970), but in the absence of the proximal end the identification will be cf.

Genus LAGAROGRAPTUS Obut & Sobolevskaya, 1968 in Obut, Sobolevskaya & Merkureva, 1968

Type species: Original designation; Lagarograptus inexpelitus Obut & Sobolevskaya, 1968, p.90; from the triangulatus zone of the Norilsk Borehole, Siberia.

Diagnosis:- Hutt, 1975

Rhabdosome long, dorsally curved; sicula long (more than 3.5 mm); thecae with strong geniculation and in some cases with genicular hood; pronounced ventral processes, probably triangular in shape and generally slightly pendent, composed of fusselar material.

Lagarograptus tenuis (Portlock, 1843)
Pl. 3, figs. 3, 4-8, Text-figs. 9a-b.

1843 Graptolithus tenuis Portlock, p.319,pl.19, fig.7.

1911 Monograptus tenuis (Portlock); Elles & Wood, p.407, pl.40, figs.2a-e, text-figs.273a-d.

1968 Monograptus tenuis Portlock; Hutt, p.252, text-figs. 1a-h.

1970 Monograptus tenuis (Portlock); Churkin & Carter, p.43 pl.4, figs.2,3 text-fig. 18D.

1974 Monograptus tenuis (Portlock); Hutt, text-fig.10, fig.5.

1975 Lagarograptus tenuis (Portlock); Hutt, pp.70-71, pl.11, fig.2; text-fig.10,fig.5.

Lectotype: Subsequent designation Hutt 1968, p.253 fig. 1a; GSM 7800; from the Sedgwickii Zone of Desertcreat, Co. Tyrone, Northern Ireland.

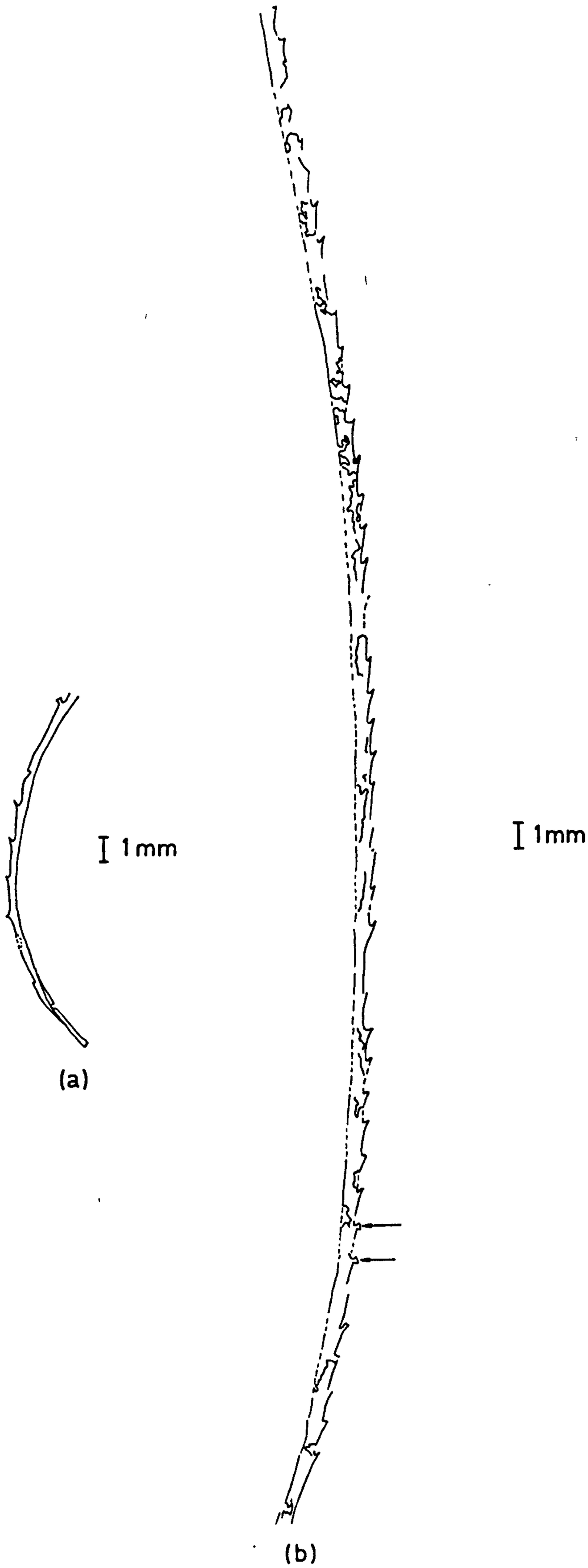
Text-fig. 9 a- Lagarograptus tenuis (Portlock)

$q_3$2a(9), proximal end, convolutus Zone, loc. Jabal Antar, Qusayba.

b- Lagarograptus tenuis (Portlock)

$q_3$6b(1), convolutus Zone, Jabal Antar, Qusayba.

Arrows sign to apertural process.


1mm
(a)
1mm
(b)

Locality and horizon:-

Jabal Antar, Qusayba, Al-Qassim, convolutus Zone, Llandovery Series, Tabuk Formation.

Material:-

More than 10 flatted specimens.

Description:-

The rhabdosome is very long, parallel-sided distally, with strong dorsal curvature proximally, becoming straight or slightly curved distally. The dorso-ventral width excluding the thecal processes is about 0.3 mm at the level of th.1, 0.5 mm at the level of th.9 and gradually increases until an average width of 0.55 mm to 0.8 mm is reached distally. The sicula is 4.3 mm in length, reaching about th.2. The thecal count 6 in 10 mm at proximal end and 8 in 10 mm at distal end. The thecae inclined (up to 20°) to the rhabdosome axis. The ventral apertural processes appear as triangular in form with a narrow neck attached to the ventral wall of the thecae.

Remarks:-

The specimens from Al-Qassim agree with the description of L. tenuis by the previous authors. Usually the apertural processes are broken off possibly due to the delicacy of the thin necks.

Genus PETALOGRAPTUS Suess, 1851

(pro Diprion Barrande, 1850, and Petalolithus Suess 1851)

Type species (subsequently designated Lapworth, 1873).

Prionotus folium Hisinger, 1837; from the Llandovery of Sweden.

Diagnosis:- Rickards, 1970.

Rhabdosome foliate, thecae at a considerable angle to axis of rhabdosome. Thecae long, nearly straight or with gentle ventral curvature, with large overlap; th.1^1 and 1^2 with pronounced upward direction of growth, leaving sicula much exposed; in cross section rhabdosome is exaggeratedly rectangular; septum partial or absent.

Petalograptus ovatoelongatus (Kurck, 1882)
Pl. 5, figs. 1, 4, 6; Text-figs. 10b-e.

1850 Graptolithus palmeus. Barr.; Barrande, pp. 59-63 (pars) pl.3, fig.7, (nonfigs. 1-6).

1882 Cephalograptus ovato-elongatus n.sp.; Kurck, p.303, pl.14, fig.10.

1908 Petalograptus palmeus var. ovato-elongatus (Kurck); Elles & Wood, pp. 277-8, text-figs. 191 a-c, pl.32, fig.4a, 2c-f (non 2a-b).

1908 Petalograptus palmeus var. latus, Barrande; Elles & Wood, pp. 275-6 (pars), text-figs. 189a-c, pl.32, figs.2c-f (non 2a-b).

1970 Petalograptus ovatoelongatus (Kurck, 1882); Rickards, p.47, pl.3, fig.4.

1974 Petalograptus ovatoelongatus (Kurck, 1882) Hutt,pp.39-40, pl.9, figs.3-5; pl.10,fig.6.

Holotype: By monotypy; figured Kurck 1882, pl.14, fig.10; from the cyphus Zone of Bollerup, Sweden.

Material:-

More than ten flattened specimens.

Locality and horizon:-

Jabal Antar, Qusayba, Al-Qassim, convolutus Zone, Llandovery Series.

Description:-

The rhabdosome is robust and distinctly ovato-elongate in outline; it is over 10 mm in length. The rhabdosome width is 3.75-4.5 mm and narrows proximally and distally. The thecae are inclined at approximately 45° and reduced at the distal end of the ovate portion. The sicula is 0.9 mm long and its apex reaches the level of first thecal pair. The thecae have concave opertural and ventral thecal margins. The distal thecae are straight and are inclined at a lower angle. Thecal count 13 in 10 mm proximally and 12 in 10 mm distally. Thecae overlap for most of their length. The septum in some specimens are observed in the obverse views.

Petalograptus minor Elles, 1897
Pl. 5, fig. 10a-b; Text-fig.10a.

1893 Diplograptus palmeus Barrande; Törnquist, pl.1, figs. 29-31.

1897 Petalograptus minor, sp. nov.; Elles, p.201, pl.14, figs. 17-21.

1908 Petalograptus minor Elles; Elles & Wood, pp. 279-81, text-figs. 193a-b, pl.32, figs. 5a-e.

1942 Petalograptus minor (Elles, 1897); Boučvek & Přibyl, p.5, pl.1, fig.3, text-figs. 1f,g.

1970 Petalograptus minor Elles, 1897; Rickards, p.48, pl.3, figs. 3,6,7.

1970 Petalograptus minor Elles; Churkin & Carter, p.32, pl.3, fig.5, text-figs.13E,F.

1974 Petalograptus minor Elles, 1897; Hutt, p.39, pl.10, figs.2, 7-10.

Lectotype: Designated Bouček & Přible 1942, p.5; figured Elles 1897, pl.14, fig.17; SM A20597; from the Llandovery of Dobb's Linn, Scotland.

Material:-

Several flattened specimens.

Locality and horizon:-

Jabal Antar, Qusayba, Al-Qassim, convolutus Zone, Llandovery Series.

Description:-

The rhabdosome is short, over 3.2 mm in length, 2.5 mm in width, and oblong in outline with rounded distal end. The sicula is slender and long, about 2 mm in length; its apex reaches the level of the apertures of the third thecal pair. Th.1^1 is 1.0 mm long and subsequent thecae are about 1.25 mm long. The proximal thecae overlap for three-quarters of their length and the overlap increased distally. The thecae are inclined at 45° to the rabdosome axis proximally and lessens distally. Thecal spacing is 13-15.5 in 10 mm. The septa are observed in the obverse views.

Text-fig. 10 a- Petalograptus minor Elles

$q_2$22b(1), convolutus Zone, loc. Jabal Antar, Qusayba.

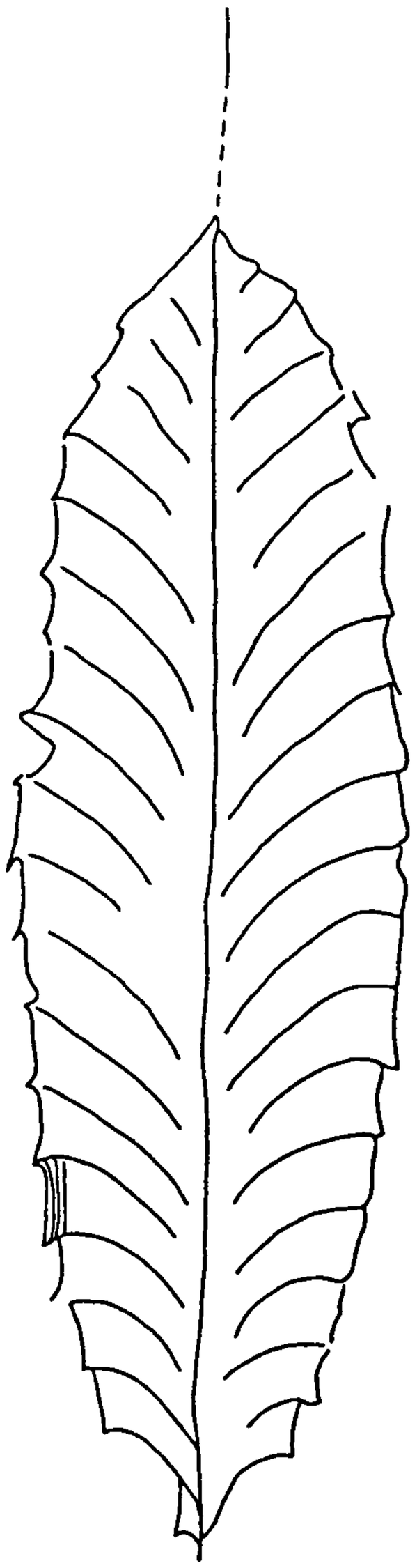
b- Petalograptus ovatoelongatus (Kurck)

$q_2$3a(1), reverse view, convolutus Zone, loc. Jabal Antar, Qusayba.

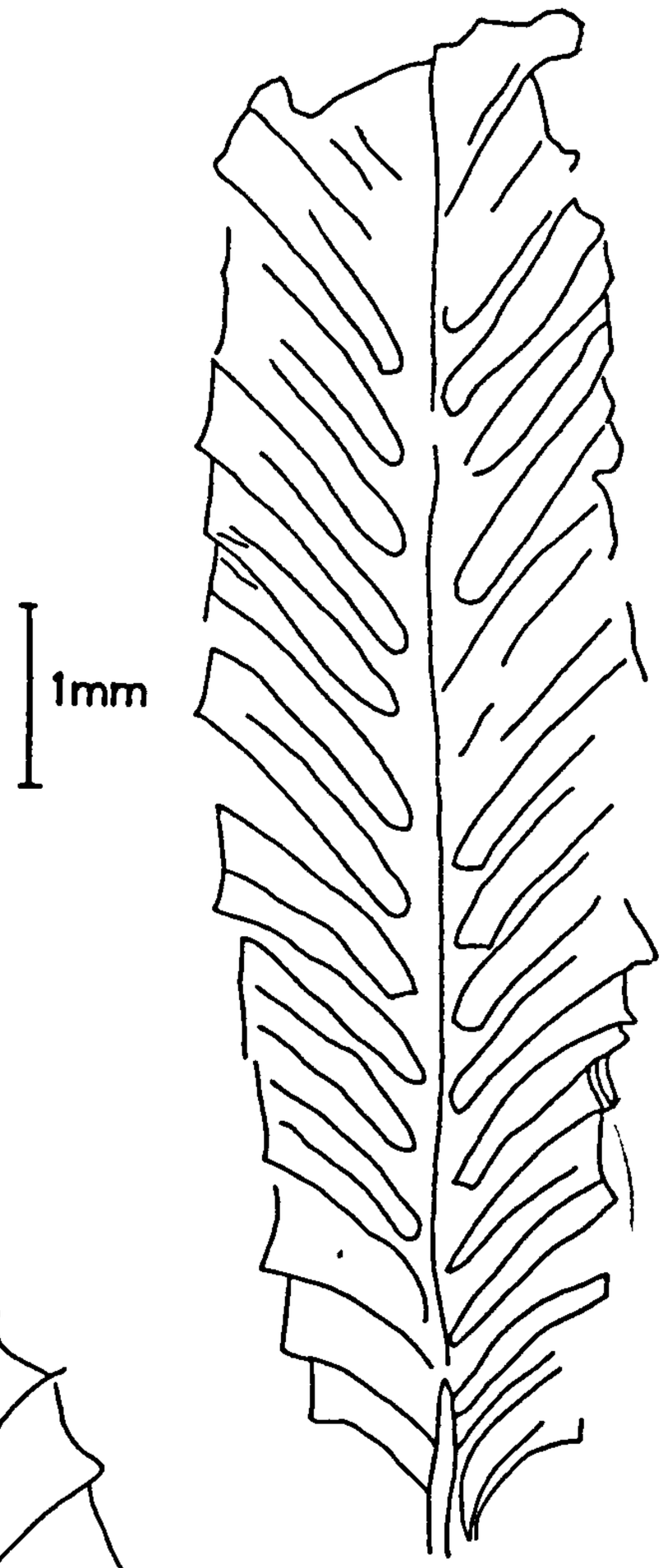
c- Petalograptus ovatoelongatus (Kurck), q_3a(2), obverse view, convolutus Zone, loc. Jabal Antar, Qusayba.

d- Petalograptus ovatoelongatus (Kurck) $q_2$27(1), convolutus Zone, loc. Jabal Antar, Qusayba.

e- Petalograptus ovatoelongatus ? (Kurck) $q_2$3C(1), early growth stage, convolutus Zone, loc. Jabal Antar, Qusayba.



(b)



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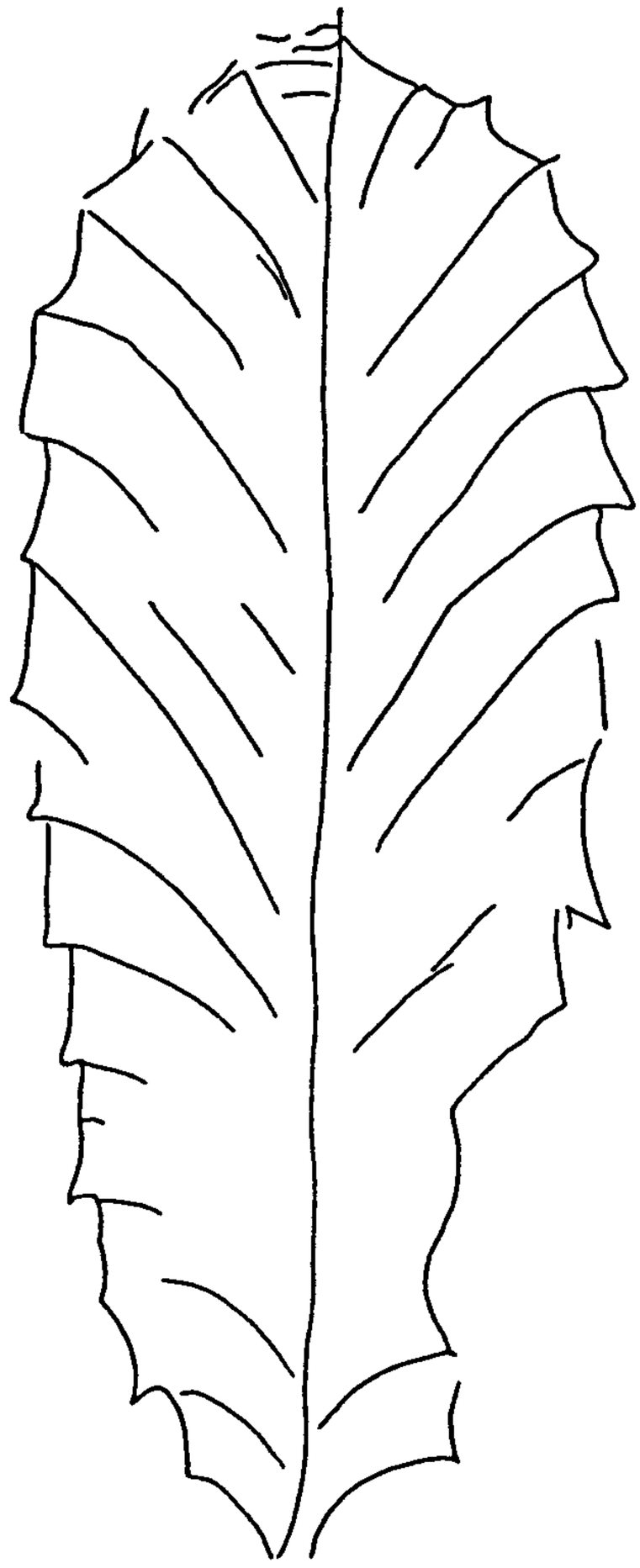

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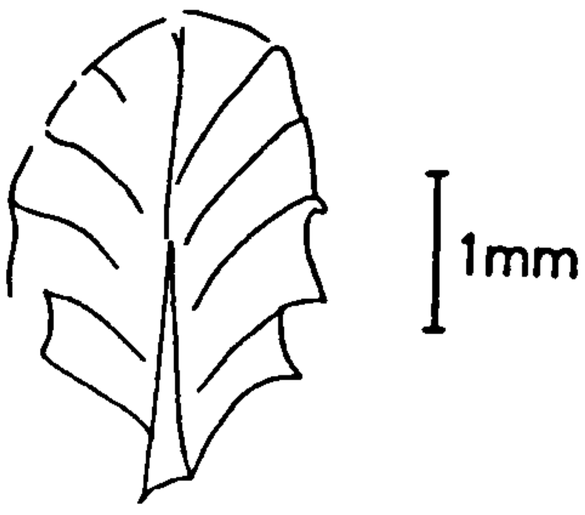
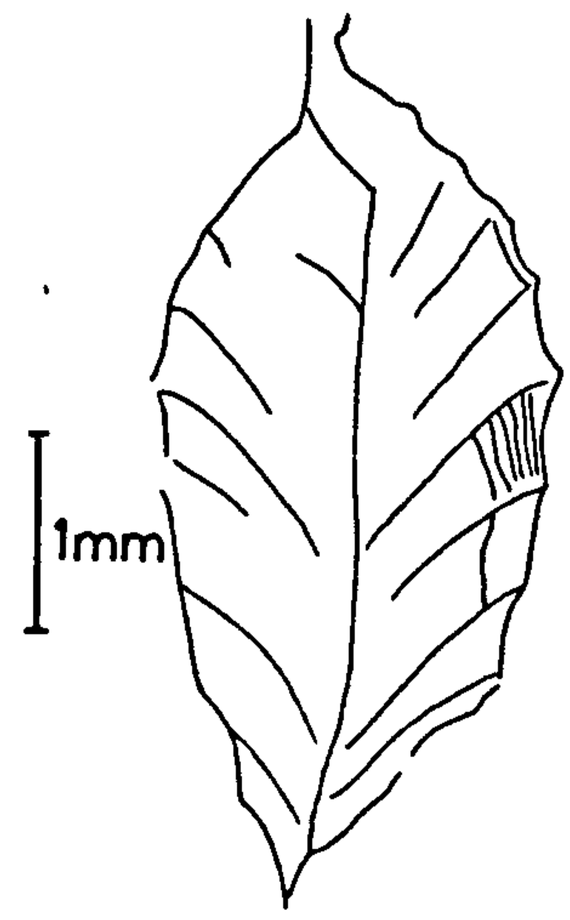


(a)



(e)

Remarks:-

It is difficult to distinguish P. minor from the early growth stage of P. ovatoelongtus. Hutt (1974) stated that narrower specimens (i.e. those 2.0-3.0 wide) could be identified as P. minor whereas the broader specimens could represent the 'ovate' portions of P. ovatoelongatus. Specimens from Al-Qassim have been confirmed with that of Hutt (1974), Rickards (1970); and Churkin & Carter (1970) for the thecal count is higher than stated by Elles & Wood (1908), in their description of P. minor.

EXPLANATION OF PLATE 3

Note: All figures approximately x 10 except where otherwise stated, specimens were photographed under alcohol. Neither prints nor negatives have been retouched.

Climacograptus cf. *normalis* Lapworth, 1877

Fig. 1 $q_1$026, subscalariform of flattened specimen, *convolutus* Zone, loc. Jabal Antar, Qusayba.

Fig. 2 q_1AB(1), scalariform of flattened specimen, *convolutus* Zone, loc. J.A. Qu.

Fig. 9 $q_1$091a, scalariform of flattened specimen, *convolutus* Zone, J.A. Qu.

Lagarograptus tenuis (Portlock, 1843)

Fig. 3 $q_3$6b(1), *convolutus* Zone, loc. J.A. Qu.

Fig. 7 $q_3$2a(1), proximal end of flattened specimen, showing the long sicula, *convolutus* Zone, loc. J.A.Qu.

Fig. 8 $q_1$03a(5), flattened specimen, showing apertural processes, *convolutus* Zone, loc. J.A. Qu., x 15.

Didymograptus bifidus (Hall, 1865)

Fig. 4 BD10(2), *Didymograptus bifidus* Zone, loc. Al-Bukayriah.

Fig. 6 BD7(1), *Didymograptus bifidus* Zone, loc. Al-Bukayriah. x 9.

Glyptograptus (G.) *incertus* (Elles & Wood, 1907)

Fig. 5 ITR081(1), obverse of flattened specimen, loc. Al-Madbaa.

Plate 3

EXPLANATION OF PLATE 4

Note: All figures approximately x 10 except where otherwise stated; specimens were photographed under alcohol.
Neither prints nor negatives have been retouched.

Monograptus cf. convolutus (Hisinger, 1837)

Fig. 1 $Q_3$1a(1), convolutus Zone, loc. Jabal Antar, Qusayba.

Fig. 4 $q_3$14b(2), convolutus Zone, loc. Jabal Antar, Qusayba.

Pristiograptus regularis regularis (Tornquist, 1899)

Fig. 2 $q_1$023b(1), proximal end of flattened specimen, convolutus Zone, loc Jabal Antar, Qusayba.

Fig. 3 $q_3$5b, part of distal end of flattened specimen, convolutus Zone, loc. Jabal Antar, Qusayba.

Fig. 7 $q_5$5(1), proximal and distal ends of flattened specimen, convolutus Zone, loc. Jabal Antar, Qusayba.

Glyptograptus (G.) incertus (Elles & Wood, 1907)

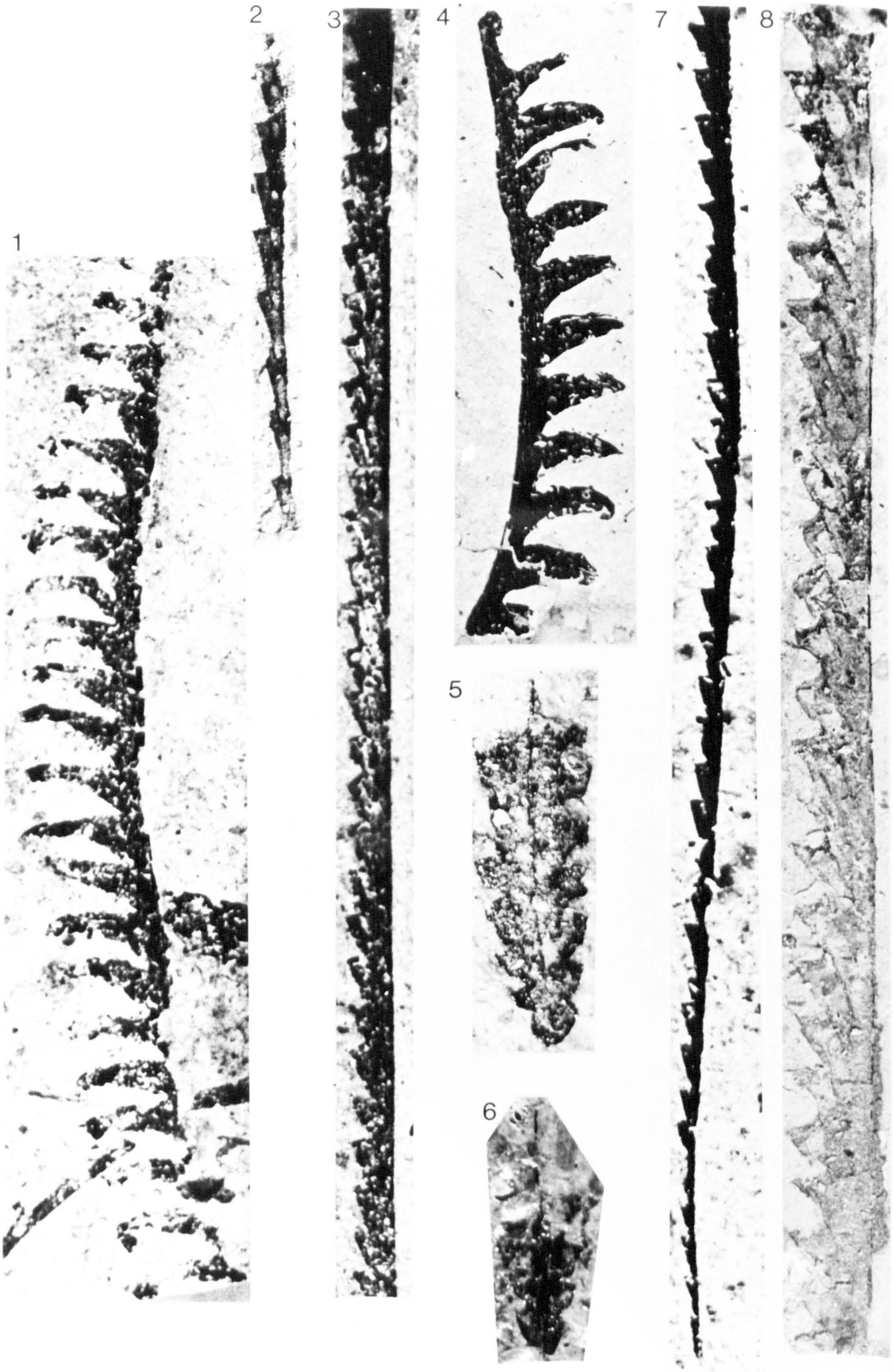
Fig. 5 ITR081(2), reverse of flattened specimen, loc. Al-Madbaa.

Fig. 6 ITR087(1), obverse of flattened specimen, loc. Al-Madbaa, x 9.

Pristiograptus cf. nudus (Lapworth, 1880)

Fig. 8 $q_5$4a(1), convolutus Zone, loc Jabal Antar, Qusayba.

Plate 4



EXPLANATION OF PLATE 5

Note: All figures approximately x 10 except where otherwise stated; specimens were photographed under alcohol. Neither prints nor negatives have been retouched.

Petalograptus ovatoelongatus (Kurck, 1882)

Fig. 1 $q_3$2a(2), obverse aspect of flattened specimen, showing sicula, convolutus Zone, loc. Jabal Antar, Qusayba.

Fig. 4 $q_2$3a(1), reverse of flattened specimen, convolutus Zone, loc. Jabal Antar, Qusayba.

Fig. 6 $q_2$27(1), convolutus Zone, loc Jabal Antar, Qusayba.

Monograptus cf. lobiferus (McCoy, 1850)

Fig. 2 $q_5$1a(1), convolutus Zone, loc. Jabal Antar, Qusayba.

Fig. 3 $q_1$023b(2), convolutus Zone, loc. Jabal Antar, Qusayba.

Monograptus cf. decipiens decipiens Tornquist, 1899

Fig. 5 $q_1$019a(1), proximal end of flattened specimen, convolutus Zone, loc. Jabal Antar, Qusayba.

Petalograptus ovatoelongatus? (Kurck, 1882)

Fig. 7 $q_2$3C(1), early growth stage of flattened specimen, convolutus Zone, loc. Jabal Antar, Qusayba.

Fig. 9 $q_1$03a(1), sicula of flattened specimen, convolutus Zone, loc. Jabal Antar, Qusayba, x 15.

Fig.11 $q_1$03a(6), early growth stage of flattened specimen, obverse view, showing sicula, convolutus Zone, loc. Jabal Antar, Qusayba, x 15.

Petalograptus minor Elles, 1897.

Fig.10 $q_2$22b(1), a- obverse view of flattened specimen, showing sicula, convolutus Zone, loc. Jabal Antar, Qusayba, b- counter part of the same specimen.

Monograptus sp.

Fig. 8 $q_3$14b(1), convolutus Zone, loc. Jabal Antar, Qusayba.

Plate 5

2. Microfossils

a. Spores and spore-like palynomorphs; acritarchs

A search for microfaunas and microfloras yielded only the palynomorphs described below. No other microfossils have been found. The absence of carbonate rocks from the sections seems to correlate with the lack of conodonts, sponges, spicules and sclerites or other fossils commonly associated with shallow-water Palaeozoic sediments.

The microfossils recorded here are from the Aeronian Stage in the section at Qusayba in the Al-Qassim district. They were found in one bed in the lower part of the section.

They are described as follows:

cf. Ambitisporites avitus Hoffmeister, 1959

Nodospora burnhamensis Strother and Traverse, 1979

Tetrahedraletes cf. medinesis Strother and Traverse, 1979

Tasmanites cf. medius (Eisenack) Downie, 1959

Ammonidium cf. cladum Downie, 1963

Baltisphaeridium cf. eoplanktonicum (Eisenack, 1955) Downie, 1959

Baltisphaeridium cf. nanum (Deflandre, 1945)(Downie, 1959) Lister, 1970

Baltisphaeridium Pilaris Cramer, 1964

Buedinisphaeridium sp.

Diexallophasis denticulata (Stockmans and Williere, 1963) Loeblich, 1970

Visbysphaera cf. piriferum (Eisenack, 1954) Downie & Sarjeant, 1963

Dictyotidium cf. dictyotum (Eisenack, 1938) 1955

Dictyotidium sp. A

Dictyotidium sp. B

Leiosphaeridia laevigata Stockmans and Williere, 1963

Leiosphaeridia cf. microcystis (Eisenack) Downie, 1959

Lophosphaeridium cf. granulosum (Staplin) Downie, 1963

Navifusa sp.

Veryhachium formosum Stockmans and Williere , 1960

Veryhachium valiente Cramer , 1964

Veryhachium sp.

Ooidium sp.

Method of study:-

Samples of the Tabuk Formation were obtained from the fresh (unweathered) surface at the Qusayba section. The descriptive morphology and nomenclature applied correspond with widespread use such as in the 'Morphologic Encyclopedia of Palynology' (Kremp, 1965), the 'Glossary of the Terminology Applied to Dinoflagellate Amphiesmae Cysts and Acritarchs' (Williams, Sarjeant & Kidson, 1978), and the glossary in Lister (1970, pp. 24-26). Measurements of the specimens have been accomplished by means of a transmitted light microscope with a graticule eye-piece at magnification x400, and x1000 (oil immersion).

Systematic description:-

Different classification of acritarchs exist for different authors. In this investigation follows the wider usage classification of Downie, Evitt, and Sarjeant (1963). The taxa treated are genera, species, subgroups under the informal incertae sedis group Acritarcha.

Genera are arranged in alphabetical order. The classification is as follows.

Incertae Sedis

Group ACRITARCHA Evitt 1963

Subgroup ACANTHOMORPHITAE Downie, Evitt, and Sarjeant 1963
Subgroup DIACROMORPHITAE Downie, Evitt, and Sarjeant 1963
Subgroup DINETROMORPHITAE Downie, Evitt, and Sarjeant 1963
Subgroup DISPHAEROMORPHITAE Downie, Evitt, and Sarjeant 1963
Subgroup HERKOMORPHITAE Downie, Evitt, and Sarjeant 1963
Subgroup NETROMORPHITAE Downie, Evitt, and Sarjeant 1963
Subgroup OOMORPHITAE Downie, Evitt, and Sarjeant 1963
Subgroup PLATYMORPHITAE Downie, Evitt, and Sarjeant 1963

Subgroup POLYGONOMORPHITAE Downie, Evitt, and Sarjeant 1963

Subgroup PRISMATOMORPHITAE Downie, Evitt, and Sarjeant 1963

Subgroup PTEROMORPHITAE Downie, Evitt, and Sarjeant 1963

Subgroup SPHAEROMORPHITAE Downie, Evitt, and Sarjeant 1963

Subgroup STEPHANOMORPHITAE Downie, Evitt, and Sarjeant 1963

For genus Tasmanites is enroled in Class PRISINOPHYCEAE(Brasier , 1980).

Genus AMBITISPORITES Hoffmeister, 1959

Type species:- Ambitisporites avitus Lower Silurian, Libya, Hoffmeister, 1959.

Diagnosis:- Hoffmeister, 1959

Trilete, radial miospore, subcircular to roundly triangular in equatorial outline, and possessing a well defined, simple trilete and an equatorial crassitudo.

cf. Ambitisporites avitus Hoffmeister, 1959

Pl. 6, figs. 2-3.

Material:-

Two specimens recorded.

Description:-

The spore is roundly triangular in equatorial outline, ornamentation laevigate. Spore with thickened exinous equatorial band (crassitudo), of about uniform width. Crassito is about 3 microns wide. The sopre diameter is about 32.5 µm.

Range:-

Lower Silurian, Libya (Hoffmeister, 1959). Tabuk Formation, Qusayba , Middle Llandovery.

Remarks:-

cf. Ambitisporites avitus differs from Ambitisporites avitus in lacking a thin laesure, this may be due to the poor preservation.

Genus NODOSPORA Strother and Traverse, 1979

Type species:- Nodospora burnhamensis, Tuscarora Formation, Lower Silurian. Strother and Traverse, 1979.

Diagnosis:- Strother and Traverse, 1979, p.10.

Tetrads of inaperaturate spores or sporelike palynomorphs, spherical to subspherical in outline, are arranged in a cross configuration; a continuous band of thickened wall follows the line of contact of the individual spore margins; the tetrad may be enclosed in a membranous sac; tetrad diameter ranges from 38 to 82 µm; walls may be smooth or ornamented.

Nodospora burnhamensis

Pl. 6, figs. 1, 5, 7.

1979 Nodospora burnhamensis. Strother & Traverse p. 10, pl.1, fig.11, 2:1,5.

Material:-

Four specimens recorded.

Description:-

Tetrads of inaperturate spores, spherical to subspherical in outline, are arranged in a cross configuration; a continuous band of thickened wall is present along the contact margins of the individual spore; the wall is smooth. Tetrad diameter ranges from 27.5 - 47 µm.

Remarks:-

These spores are identical to those described by Strother and Traverse (1979) but the tetrad diameters have smallar size.

Range:-

Tuscarora Formation (Llandoverian) Pennsylvania. (Wenlockian) eastern Pennsylvania. (Strother and Traverse, 1979). Tabuk Formation, Qusayba , Middle Llandovery.

Genus TETRAHEDRALETES Strother and Traverse, 1979

Monotype genus:- Tetrahedraletes medinensis

Diagnosis:- Strother and Traverse, 1979, p.8

Tetrads of inaperaturate, subtriangular spores or spore-like palynomorphs arranged in tightly adhering tetrahedral configuration; spore walls collapsed towards tetrad centre; contact margins between the individual spores thickened, forming a dark ring around the margin of each spore.

Tetrahedraletes cf. medinesis

Pl. 6, fig. 4,8,11.

1979 Tetrahedraletes medinesis Strother & Traverse p.8, pl.1, fig.5, 14-17.

Material:-

Four specimens recorded.

Description:-

Inaperturate tetrads, sub-triangular in outline, tetrads are arranged in tightly adhering tetrahedral configuration; contact margins between the individual spores are thickened. Wall surface is psilate. Tetrad diameter ranges from 25 - 35 μm.

Range:-

Power Glenn Formation, Niagara Falls, New York (Gray and Boucot, 1971). Tuscarora Formation, Rocks of Pennsylvania. (Llandoverian age) (Strother and Traverse, 1979). Tabuk Formation, Qusayba, Middle Llandovery.

Class PRASINOPHYCEAE

Genus TASMANITES (Newton, 1875) Eisenack, 1958

Type species:- Tasmanites punctatus Newton, 1875.

Diagnosis:- Eisenack, 1958

Spherical, hollow or compressed, thick-walled organisms consisting of a yellowish to red brown organic substance; wall with numerous or relatively few radial pores, which may end blindly in the wall; a pylome may be present.

Tasmanites cf. medius (Eisenack) Downie, 1959
Pl.6, figs. 6,10.

1958 Tasmanites medius Eisenack, p.6.

1959 Tasmanites medius Downie, p.67, pl.12, fig.5.

Material:-

Two specimens recorded.

Description:-

The body is spherical, about 57μ in diameter. The surface is smooth with pores. The wall thickness is about 2μ.

Remark:-

T. cf. medius is different from T. medius in its thinner wall and smaller diameter.

Occurrence:-

Jabal Antar, Qusyaba , Al-Qassim, Middle Llandovery, Tabuk Formation.

Incertae Sedis

Group ACRITARCHA Evitt, 1963

Subgroup ACANTHOMORPHITAE Downie, Evitt and Sarjeant, 1963

Genus AMMONIDIUM Lister, 1970

Type species:- Baltisphaeridium microcladum Downie, 1963, p.645, pl.92, fig.6, Wenlock Shale, Harley Brook, Shropshire.

Diagnosis:- Lister, 1970

Visicle hollow, spherical to ellipsoidal, single-walled, vesicle wall smooth or sculptured. Processes numerous, evenly spaced, more or less rigid, hollow, tapering, communicating freely with the vesicle cavity, distally the processes have equifurcate terminations. Excystment by cryptosuture apical or near-equatorial.

Remarks:-

Lister (1970) stated that the genus differs from Multiplicisphaeridium in exhibiting only one order of process branching. All the branches arise from a single node at the extreme distal end of the process shaft, and on a given process all branches are of equal length. The great variability of branching exhibited by species of Multiplicisphaeridium is not present in Ammonidium. In a given specimen all the processes appear identical, although minor variation may occur in the number of branches. The homomorphic character of the processes is highly typical and in marked contradistinction to Multiplicisphaeridium.

Ammonidium cf. cladum Downie, 1963

Pl. 7, figs. 14-15.

1963 Baltisphaeridium cladum; Downie, pp. 643-644, pl.92, fig.5, text-fig.3a.

1970 Baltisphaeridium cladum; Cramer, p.126, pl.VIII, fig.136, text-fig. 39, fig. h.

Material:-

Twenty specimens recorded.

Description:-

The vesicle is spherical to subspherical. The processes distribute regularly, fourteen to twenty visible in optical section. The processes are short and bifurcated. The splitting angle is fairly wide. The processes are hollow and communicate freely with vesicle cavity. The vesicle wall is psilate.

Dimension:-

Vesical diameter = 25 - 30 μ processes length 38 μ.

Remarks:-

A. cf. cladum differs from A. cladum by having thin, and short processes.

Occurrence:-

Jabal Antar, Qusayba, Al-Qassim, Tabuk Formation, Middle Llandovery.

Genus BALTISPHAERIDIUM (Eisenack, 1958),Downie & Sarjeant, 1963.

Type species:- Baltisphaeridium longispinosum (Eisenack, 1931), Eisenack, 1959, p.194, p.15, fig.1.

Diagnosis:- Downie & Sarjeant, 1963, p.89.

Hystrichospheres with spherical to oval shell, not divided into fields or plates, bearing numerous processes, simple, branching or ramifying, hollow to solid, always with closed tips. The processes are not connected together distally and no outer shell, complete or incomplete, is present: the processes are most often of a single basic type, but processes of two or more types may be present. Mean and modal diameter of shell greater than 20 μ.

Baltisphaeridium cf. eoplanktonicum (Eisenack, 1955)
Downie, 1959
Pl. 8, figs. 7, 10.

1955 Hystrichosphaeridium eoplanktonicum Eisenack, pp. 178-179, pl.4, fig.14.

1959 Baltisphaeridium eoplanktonicum Downie, p.60, pl.10, fig.3.

1963 Baltisphaeridium eoplanktonicum Downie, p.643.

1970 Baltisphaeridium eoplanktonicum Cramer, pp.128-129, pl.VIII, 129, 131, 134, fig.39b.

Material:-

Three specimens recorded.

Description:-

The vesicle is spherical and hollow. The processes are clearly differentiated from the vesicle but communicate directly with the vesicle cavity. The vesicle exhibits few processes about (3-4). The processes distribute regularly and symmetrically and are shorter than the vesicle diameter. They are distally branched in an irregular fashion. The first pinnae originate about the distal end. A splitting pattern may occur. The vesicle wall is thin and unilayered.

Remarks:-

In comparison with B. cf. eoplanktonicum, B. eoplanktonicum species generally, the processes are longer than the vesicle diameter.

Occurrence:-

Jabal Antar, Qusayba, Al-Qassim, Tabuk Formation, Middle Llandovery.

Baltisphaeridium cf. nanum (Deflandre, 1945)
(Downie, 1959) Lister, 1970
Pl. 7, fig. 7.

1945 Hystrichosphaeridium brevispinosum. var. nanum; Deflandre, pp. 62-3, pl.1, figs.5-7, 17, 18.

1959 Baltisphaeridium brevispinosum; var. nanum; Downie, p.59, pl.10, fig.9.

1959 Baltisphaeridium brevispinosum; var. wenlockensis, Downie, p.59, pl.10, fig.4.

1966 Baltisphaeridium nanum; Martin, pp. 2-3, pl.1, fig.10.

1967 Baltisphaeridium wenlockensis; Lister & Downie, pl.23, fig.3.

1970 Baltisphaeridium nanum; Lister, pp.54-56, pl.2, figs.6-12, text-fig. 17K.

Material:-

One specimen recorded.

Description:-

The vesicle is ellipsoidal and hollow. The vesicle wall is single and psilate. The processes, about 30 in number, are smooth, hollow and freely communicate with the vesicle cavity. The processes are homomorphic, non-branching and conical in shape, tapering distally.

Remarks:-

B. cf. nanum differs from other species such as B. nanum Lister, B. lucidum Denuff, B. hirsutoides var. hamatum Downie, B. hirsuoid Eisenack by having proximally broad and short processes. The other species in general possess fewer than 30 processes.

Occurrence:-

Jabal Antar, Qusayba, Al-Qassim, Tabuk Formation, Middle Llandovery.

Baltisphaeridium pilaris Cramer, 1964

Pl. 7, figs. 4, 13.

1964 Baltisphaeridium pilar; Cramer, p.286, pl.I:1,2,fig.14:1.

1966 Baltisphaeridium pilaris; Cramer, pp.30-33, pl.I:1-9,II:1-3,5-11.

1970 Baltisphaeridium pilaris; Cramer, pp.165-166, pl.9: 145-148, pl.13: 187,188,190,191, pl.18: 256-266,267.

Material:-

Three specimens recorded.

Description:-

The vesicle is subspherical. It is single-walled. The central body and processes are hollow. The processes communicate directly with the vesicle cavity. The processes have the form of slender pilars with lobulate branching. Number of processes is three. The vesicle wall is thin.

Remark:-

Some of the specimens have shorter processes than that of B. pilaris Cramer.

Occurrence:-

Jabal Antar, Qusayba, Al-Qassim, Tabuk Formation, Middle Llandovery.

Genus BUEDINGIISPHAERIDIUM (Schaarschmidt, 1963)
Lister, 1970.

Type species:- Buedingiisphaeridium permicum Schaarschmidt, 1963, p.70, pl.20, figs. 4-6, text-fig. 26; from the Upper Permian (Zechstein), Germany.

Diagnosis:- Lister, 1970

Vesicle spherical, of moderate size, wall firm, ornamented with low verrucae or conical hollow tubercles, closed at the tip, sometimes thickened at the tip, but always partially hollow, communicating with vesicle interior.

Remarks:-

Lister (1970) stated that the type species of Lophosphaeridium, L. rarum Timofeyev, has an ornament of solid tubercles taking this diagnostic character into account (following Downie et al., 1963, p.8) to

enrolled Lophosphaeridium in subgroup Sphaerophitae.

Buedingisphaeridium sp.

pl. 8 , fig. 6

Material:-

Four recorded specimens.

Description:-

The vesicle is spherical to subspherical. The vesicle wall is thin, ornamented with low verrucae closed at tip and the verrucae communicate freely with the vesicle cavity.

Dimensions:-

Vesicle diameter = 45 μ, height of ornament 4 μ, width at base of ornament = 0.5 μ.

Occurrence:-

Jabal Antar, Qusayba, Al-Qassim, Tabuk Formation, Middle Llandovery.

Genus DIEXALLOPHASIS Loeblich, 1970

Type species:- Diexallophasis denticulata (Stockmans and Willière).

Diagnosis:- Loeblich, 1970

Central body inflated, in life probably spherical or subspherical, or variable outline when compressed. Wall thin, no differentiation in wall between central body and processes with small spines: the 4-10 commonly 6 hollow processes communicate freely with central body, processes are of two types, one smaller, smooth and unbranched and the other spinose, bifurcate or multifurcate and extremely variable in diameter: excyment by simple rupture of the central body.

Remarks:-

Loeblich (1970) stated that Diexallophasis is similar to Multiplicisphaeridium Staplin, 1961 in showing no differentiation in wall character between processes and central body, except for the prominent ornamentation on the two elements, it differs from Baltisphaeridium Eisenack, 1958, in the process communicating freely with the central body and in showing no tendency for the process to close off at its junction with the central body.

Diexallophasis denticulata (Stockmans & Willière 1963)
Loeblich, 1970
Pl. 7, figs. 3,8.

1963 Baltisphaeridium denticulata Stockmans and Willière, p. 458, pl.1, fig.4, text-fig. 13.

1970 Baltisphaeridium denticulata(Stockmans and Willière) Loeblich, pp. 715-716, figs. 8 A-E:9 A-C

Material:-

Five specimens recorded.

Description;-

The vesicle is spherical or subspherical, and the wall is thin. No differentiation in wall between processes and vesicle except that the denticulate or the small low grana are mostly concentrated on the process. The number of processes, varies from four to eight, commonly five.

Processes are cylindrical to columnar in shape, hollow, with direct communication with vesicle cavity. The vesicle wall is psilate. The branching pattern at the distal end is variable, unbranched or bifurcate type. No excysment is known.

Remarks:-

This species is very similar to Baltispheridium denticulatum ontariensis Cramer, 1969 in having a light cover of medium-sized echinae.

Occurrence:-

Jabal Antar, Qusayba, Al-Qassim, Tabuk Formation, Middle Llandovery.

Genus VISBYSPHAERA Lister, 1970

Type species:- Baltisphaeridium dilatispinosum Downie, 1963, p.642, pl.92, fig.4; from the Wenlock Shale, Harley Brook, Shropshire.

Diagnosis:- Lister, 1970

Vesicle hollow, spherical to ellipsoidal, occasionally sub-triangular, smooth or sculptured, double-walled. Inner wall confined to the vesicle and usually closely appressed to the outer wall. Processes hollow, composed of the thin outer wall only,

usually much less than half the vesicle diameter in length, generally numerous, heteromorphic and often variable in size within a single individual. Excystment by cryptosuture.

Visbysphaera cf. piriferum (Eisenack, 1954) Downie & Sarjeant, 1963

Pl. 8, fig. 15.

1954 Hystrichosphaeridium piriferum Eisenack, p.206, pl.1,fig.1.

1963 Baltisphaeridium dilatispinosum Downie, p.642, pl.92, fig.4.

1965 Baltisphaeridium piriferum Eisenack, p.263, pl.21, fig.1.

1966 Baltisphaeridium dilatispinosum, Cramer, pp. 35-36, pl.IV:1, fig.4.

1967 Baltisphaeridium dilatispinosum, Cramer, p.248, pl.I:10, fig:3:9.

1968 Baltisphaeridium hermosum, Cramer & Diez, De Cramer, p. 567, pl.111, fig.4.7.

1969 Baltisphaeridium piriferum, Cramer, pp.486 ff.

Material:-

One specimen recorded.

Description:-

The vesicle is spherical; the vesicle wall is smooth. The processes distribute regularly. The processes are numerous and relatively short, baculate or blister-like.

Remarks:-

This species differs from Visbysphaera piriferum by having a tiny baculate processes.

Occurrence:-

Jabal Antar, Qusayba, Tabuk Formation, Middle Llandovery.

Subgroup HERKOMORPHITAE Downie, Evitt and Sarjeant, 1963

Genus DICTYOTIDIUM (Eisenack, 1955) Staplin, 1961

Type species:- Dictyotidium dictyotum (Eisenack) Eisenack, 1955

Diagnosis:- Staplin, 1961

Vesicle spherical; surface reticulate, ridges low, distinct smaller lacunae, one at each pole; small apiculae or spines may arise from the ridges; papillae may be present in the floors of lacunae.

Remarks:-

Staplin has enlarged the genus to include forms with differential polar polygons and with short spines or apiculae on the ridges.

Dictyotidium cf. dictyotum (Eisenack, 1938) 1955.
pl.7 , figs. 10, 12.

1938 Leiosphaera dictyota Eisenack, p.27, pl.3, figs.8a-c.

1955 Dictyotidium dictyotum (Eisenack, 1938), Eisenack pp. 179-180, pl.4, figs.12-13.

Material:-

Six specimens recorded.

Description:-

The vesicle is ellipsoidal ornamented with low, prominent ridges (muri) which form a network of relatively large polygons. The sides of each polygon are usually straight. From the corners of the polygons short spines project outwards and it can be seen clearly on the rim of the vesicle. The vesicle size is about 34 μ.

Remarks:-

D. cf. dictyotum is different from D. dictoytum Eisenack in its small size. Also there is a difference from D. tenniornatum Eisenack and D. stenodictyum Eisenack, as the former

has a large size, delicate and low ridges which the lacunae hardly can be seen. D. stenodictyum has polygonal outlines smaller than in D. dictyotum. Some of the D. stenodictyum lacunae have star-shaped punctae.

Occurrence:-

Jabal Antar, Qusayba, Al-Qassim, Middle Llandcvery, Tabuk Formation.

Dictyotidium sp. A

pl. 7 fig. 9

Material:-

Six specimens recorded.

Description:-

The vesicle is spheroidal with outline roundly. The vesicle surface divided into polygonal lacunae, with low thin muri. Tiny spines may arise outwards from the corners of the polygons. The vesicle size is about 22 μ.

Remarks:-

Specimens of Dictyotidium sp. A are different from D. dictyotum and D. Stenodictyum both are generally larger and the former has coarse, large reticulate. The second has some of its lacunae star-shaped punctae. Also D. sp.A differs from D. cf. dictyolum by its small size of vesicle and lacunae.

Occurrence:-

Jabal Antar, Qusayba, Al-Qassim, Middle Llandovery, Tabuk Formation.

Dictyotidium sp.B

pl.7 , figs. 5,11.

Material:-

Five specimens recorded.

Description:-

The vesicle is spheroidal to ellipsoidal, with outline round to elliptical. The surface of the vesicle is divided into numerous, irregular polygons. Some of the lacunae run to small subcircular or a point. The muri of the vesicle is prominent, low and thin. The vesicle size 33-62.

Remarks:-

The specimens of Dictyotidium. sp. B. are different from those previously described here in having very small lacunae. The vesicle wall is thicker.

Occurrence:-

Jabal Antar, Qusayba, Al-Qassim, Middle Llandovery, Tabuk Formation.

Subgroup OOMORPHITAE

Genus OOIDIUM Timofeyev, 1957

Type species:- Ooidium rossicum Timofeyev, 1957; subsequently designated by Norris and Sarjeant, 1965, p.45.

Diagnosis:- Loeblich, 1970

Cysts with subcircular-ovate to elongate-ovate outline, one pole crowned with anastomosing trabeculae; wall surface commonly striate below the trabeculate portion, with lower portion of body granulate or psilate; no excystment mechanism observed.

Remarks:- Loeblich (1970) in his remarks regarded Zonooidium as a synonym of Ooidium.

Ooidium sp.

pl. 7 , fig. 6

Material:-

One specimen recorded.

Description:-

The body is subcircular in outline, and the wall is about 0.5 μ thickness; most of the body is ornamented by prominent grana which give the body surface a microserrate appearance. At the summit atrabecula appear as small arches.

Occurrence:-

Jabal Antar, Qusayba, Al-Qassim, Middle Llandovery, Tabuk Formation.

Subgroup SPHAEROMORPHITAE Downie, Evitt, Sarjeant, 1963

Genus LEIOSPHAERIDIA (Eisenack, 1958), Downie & Sarjeant, 1963

Type species:- Leiosphaeridia baltica Eisenack, 1958, Ordovician.

Diagnosis:- Downie and Sarjeant, 1963.

Spherical to ellipsoidal bodies without processes, often collapsed or folded, with or without pylomes. Walls granular, punctate or unornamented, thin without divisions into fields without transverse or longitudinal furrows or girdles.

Leiosphaeridia laevigata Stockmans & Willière, 1963

pl. 7 ,fig. 1, Pl. 8, fig. 1.

1963 Leiosphaeridia laevigata Stockmans & Willière, pp.473-474, pl.3, fig.28.

Material:-

Three specimens recorded.

Description:-

The body is spherical, often folded, the surface is smooth and transparent. Diameter is about 70 μ. The wall is very thin.

Occurrence:-

Jabal Antar, Qusayba, Al-Qassim, Middle Llandovery, Tabuk Formation.

Leiosphaeridia cf. microcystis (Eisenack) Downie, 1959

pl. 8 , fig. 4.

Material:-

One specimen recorded.

1958 Leiosphaeridia microsystis Eisenack pp. 8-9, pl.2, fig.6.

1959 Leiosphaeridia cf. microsystis Downie, pp. 66-67, pl.12, fig.1.

1963 Leiosphaeridia cf. microsystis Downie, p.629 (no fig.)

1970 Leiosphaeridia microsystis Lister, p.17 (no fig.)

Description:-

The body is spherical and the surface is smooth. The colour of the body is dark yellow to brown. The wall thickness is fairly thick about 2μ.

Remarks:-

L. cf. microsystis is different from L. laevigata in its small size. Also the wall is thicker.

Occurrence:-

Jabal Antar, Qusayba, Al-Qassim, Middle Llandovery, Tabuk Formation.

Genus SPHAEROMORPHITAE Timofeyev, 1959

Type species:- Lophosphaeridium rarum Timofeyev, designated by Downie (1963), Lower Ordovician U.S.S.R.

Diagnosis:- Downie, 1963

Agenus characterised by its solid tubercules which distinguish it from Leiosphaeridia. It includes forms with short solid spines with rounded or capitate ends.

Lophosphaeridium cf. granulosum (Staplin) Downie, 1963

pl. 8 , figs. 12-14.

Material:- Eight specimens recorded.

1961 Protoliosphaeridium granulosum Staplin, p.406, pl.48, fig.1.

1963 Lophosphaeridium granulosum Downie, p.630 (no. fig.).

Description:-

The vesicle is spherical to ellipsoidal, and 18 - 23 μ in diameter. It is ornamented with diminutive baculates. The baculates are evenly spaced. A folding may be present.

Occurrence:-

Jabal Antar, Qusayba, Al-Qassim, Middle Llandovery, Tabuk Formation.

Subgroup NETROMORPHITAE

Genus NAVIFUSA Combaz, Lange & Pansart, 1967

Type species:- Leiofusa navis (Eisenack) Combaz, Lange and Pansart, 1967.

Diagnosis:- Combaz, Lange & Pansart, 1967.

Shell in the form of a more or less elongated ellipse or of a rod with rounded extremities, vesicle wall simple, smooth or ornamented.

Navifusa sp.

pl. 7 , fig. 2

Material:-

Two specimens recorded.

Description:-

The vesicle is naviform with broadly rounded ends, elongate to squat . The vesicle wall is thin and psilate or may be faintly scabrate. The length is about 33 μ and the breadth about 21 μ.

Remarks:-

Navifusa sp.is similar in general to Leiovalia similis, Eisenack's species (1965a) which, however, is much larger (length 124-149, breadth 70 μ). N. sp. also differs from Navifusa bacillum (Deunff) Playford 1977 which has a thicker granulate vesicle wall and is large in size. Navifusa sp. is similar to Navifusa exilis Playford (1981); but the length: breadth ratio is lower, 1.6 to 1.

Occurrence:-

Jabal Antar, Qusayba, Al-Qassim, Middle Llandovery, Tabuk Formation.

Subgroup POLYGONOMORPHITAE Downie, Evitt & Sarjeant, 1963

Genus VERYHACHIUM Deunff ex Downie 1959.

Type species:- Veryhachium trisulcum Deunff, 1954 subsequently designated by Downie, 1959, p.62.

Diagnosis:- Loeblich & Tappan, 1969

Vesicle thin walled, polygonal with processes from the angles forming an integral part of vesicle, major processes in a single plane, commonly with accessory processes at various positions on the vesicle, processes distally closed and simple. Surface may be ornamented with grana, prickles or small spines or may be smooth. Excystment involves formation of large aperture, originating as an arched slit between two of the processes. Subsequent rupture allows a relatively large flap to fold back (the epityche). Rarely a small nipple occurs at the centre of the flap, which fits into a corresponding notch on the central body.

Veryhachium valiente Cramer, 1964

pl. 8 , figs. 9,11.

Material:-

Two specimens recorded.

1964 Veryhachium valiente Cramer, p.34, (no fig.).

1970 Veryhachium valiente Cramer; Loeblich, pp. 744-745, figs. 36c-e.

1970 Veryhachium valiente Cramer, p.100, (no fig.).

1972 Veryhachium valiente Cramer & Diez de Cramer, p.169.

Description:-

The vesicle is rectangular in outline, and has concave sides depending on the nature of preservation. The processes are drawn

out at each corner of the body. The wall is thin and the surface of the body is psilate. The processes communicate freely with central body cavity. No excystment has been observed.

Remarks:-

The processes of the body have been broken off due to deformation, Veryhachium valiente resembles Veryhachium lairdi (Deflandre) Deunff 1955, but Cramer (1964) distinguished between them as V. valiente possessed straight sides to the central body whereas V. lairdi possessed curved sides. Loeblich (1970) agreed with Martin (1969) that considering the limits in V. valiente is variable, and referred V. valiente as proper name for the Silurian species, and V. lairdi(Deflandre) ex Deunff is for the Ordovician species. Here I have followed this opinion.

Occurrence:-

Jabal Antar, Qusayba, Al-Qassim, Middle Llandovery, Tabuk Formation.

Veryhachium formosum Stockmans & Williere, 1960

pl. 8 , figs. 5,8.

1960 Veryhachium formosum Stockman & Williere, p.2, pl.2, fig.28.

1963 Veryhachium formosum Wall & Downie, p.783.

1970 Veryhachium formosum Cramer, p.97, text-fig. 28.

Material:-

Two specimens recorded.

Description:-

The vesicle is triangular in outline, with a single simple process emerging from each angle. A similar one emerges from the central part of the vesicle. The surface of the body is smooth. The processes communicate freely with vesicle cavity.

Remarks:-

The branching pattern of some processes is bifurcated.

Occurrence:-

Jabal Antar, Qusayba, Al-Qassim, Aeronian Stage.

Veryhachium sp.

pl. 8 , figs. 2,3.

Material:-

Three specimens recorded.

Description:-

A Veryhachium of small size, triangular in outline. The sides of the vesicle are straight or slightly convex, with only three short processes emerging from each corner of the triangle. The surface of the vesicle is smooth with a series of low and obscure ridges. The processes communicate freely with the vesicle cavity.

Occurrence:-

Jabal Antar, Qusayba, Al-Qassim, Middle Llandovery, Tabuk Formation.

Fragmented Remains
Pl. 6, figs. 9, 12,13.

Amongst the organic remains to have been extracted with acritarchs and spores are two kinds; cuticle-like fragment and tubular structures. Cuticle-like materials (cuticles) consist of articulate patterns of ridges which show a network of irregular circular forms, "cellular". (Strother and Traverse, 1979). The second kind of the tubular structure consist of small unbranched filaments which are either straight or slightly bent (Strother and Traverse, 1979).

Other species in the Assemblage

A number of other species are present and are not being described here. Micrhystridium is represented in a small number of samples with thin walls and long simple processes, Veryhachium cf. trispinosum also is represented in a few.

EXPLANATION OF PLATE 6

Note: All figures x 1000 unless indicated otherwise.

Nodospora burnhamensis Strother & Traverse, 1979

Fig. 1 q_1PO27bH, loc. Jabal Antar, Qusayba.

Fig. 5 q_1PO27bA, loc. Jabal Antar, Qusayba.

Fig. 7 q_1PO27bA, loc. Jabal Antar, Qusayba.

cf. Ambitisporites avitus Hoffmeister, 1959

Fig. 2 q_1PO27bH, loc. Jabal Antar, Qusayba.

Fig. 3 q_1PO27bc, loc. Jabal Antar, Qusayba.

Tetrahedraletes cf. medinesis Strother and Traverse, 1979

Fig. 4 q_1PO27bG, loc. Jabal Antar, Qusayba.

Fig. 8 q_1PO27bO, loc. Jabal Antar, Qusayba.

Fig. 11 q_1PO27bCa, loc. Jabal Antar, Qusayba.

Tasmanites cf. medius (Eisenack) Downie, 1959.

Fig. 6 q_1PO27bG, loc. Jabal Antar, Qusayba.

Fig. 10 q_1PO27bO, loc. Jabal Antar, Qusayba.

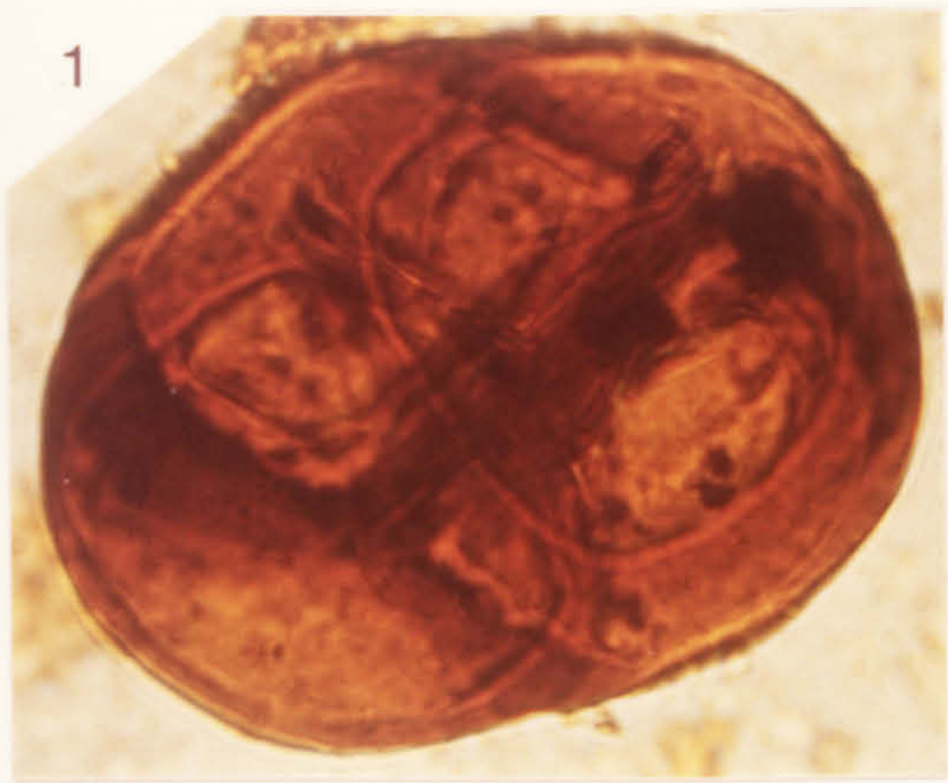
Fragmented Remains

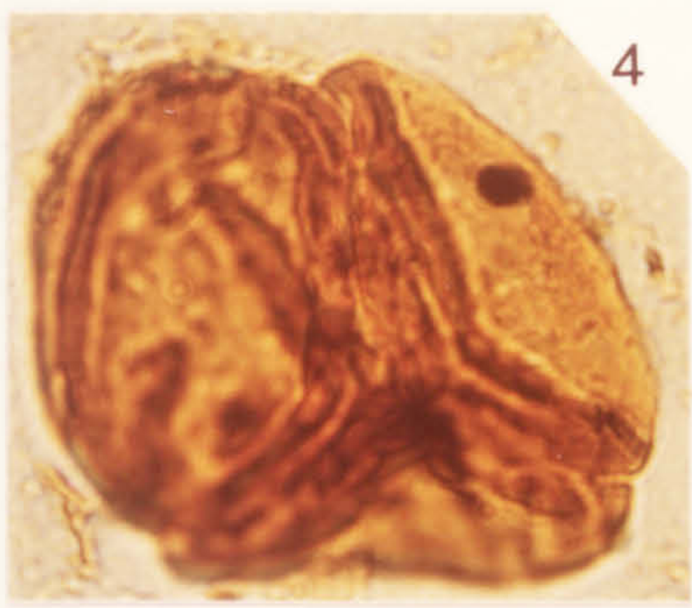
Fig. 9 q_1PO27bN, tubular structure, loc. Jabal Antar, Qusayba.

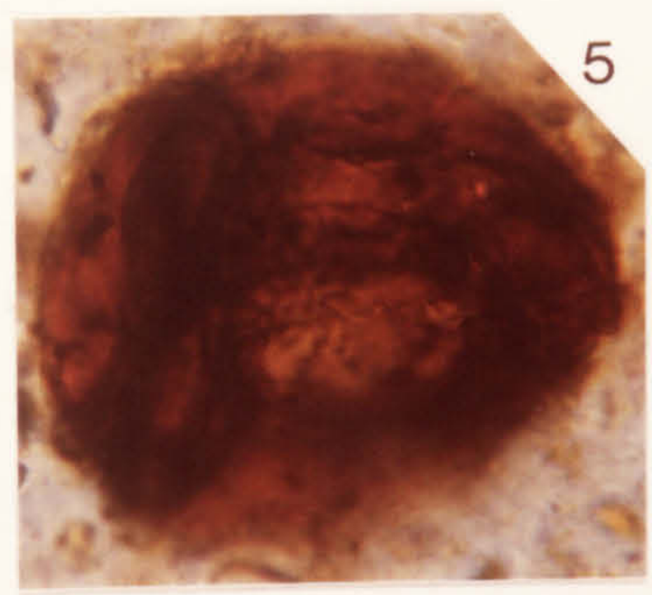
Fig. 2 q_1PO27b, network of circular forms,loc. Jabal Antar, Qusayba.

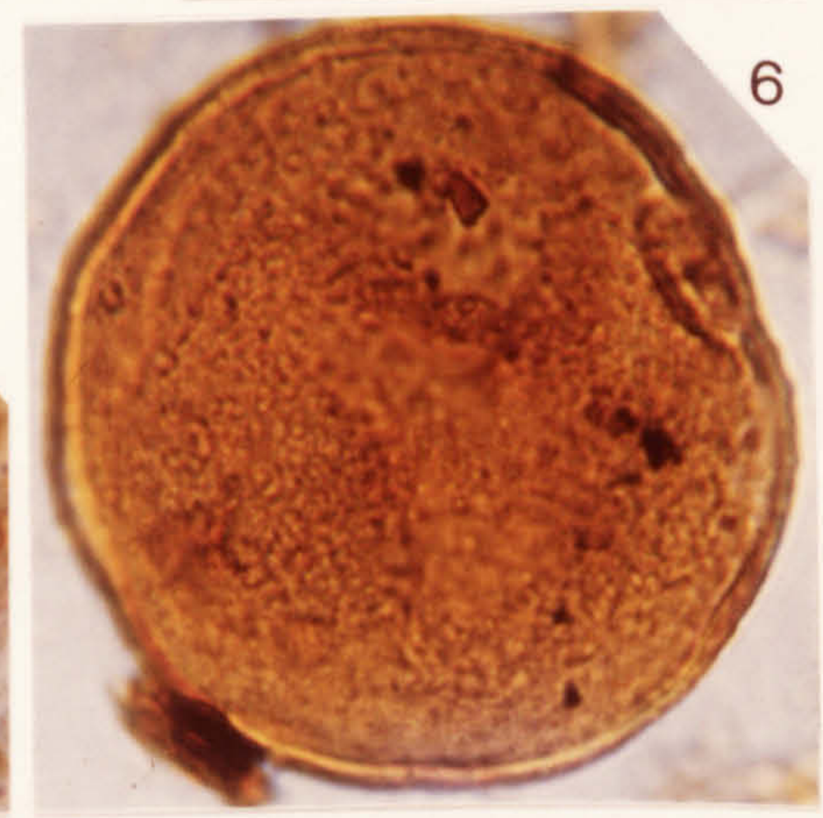
Fig. 13 q_1PO27bL, tubular structure, loc. Jabal Antar, Qusayba.

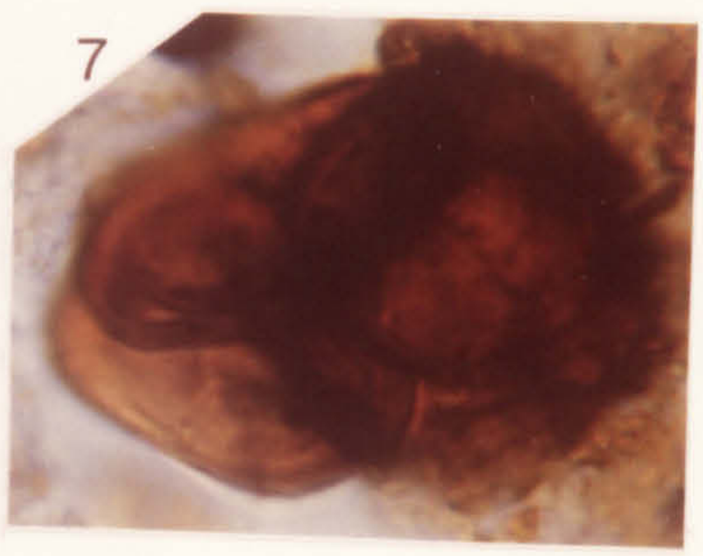
Plate 6

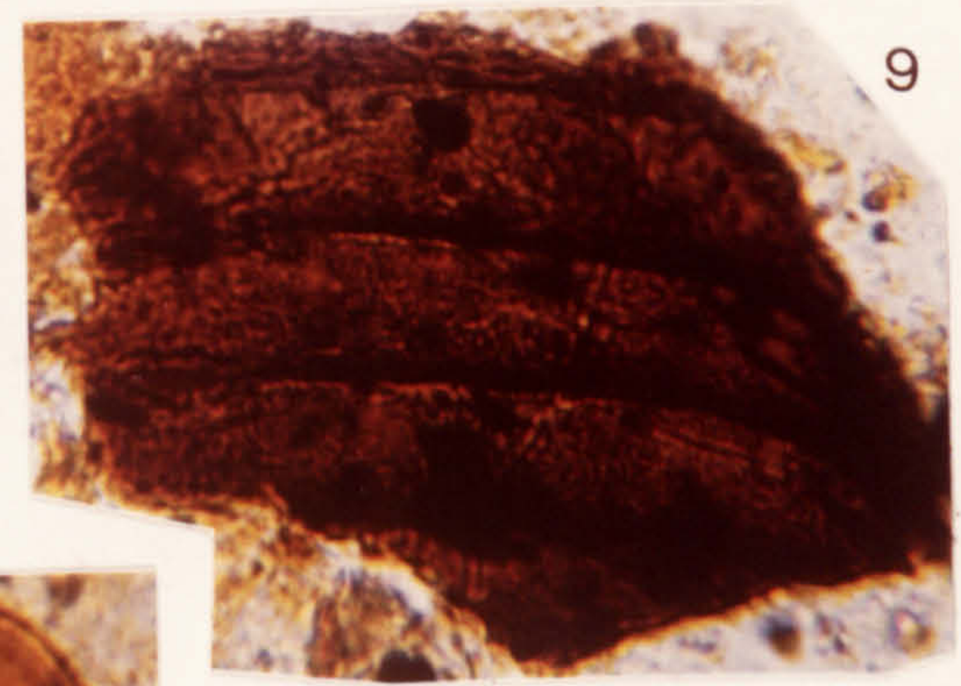


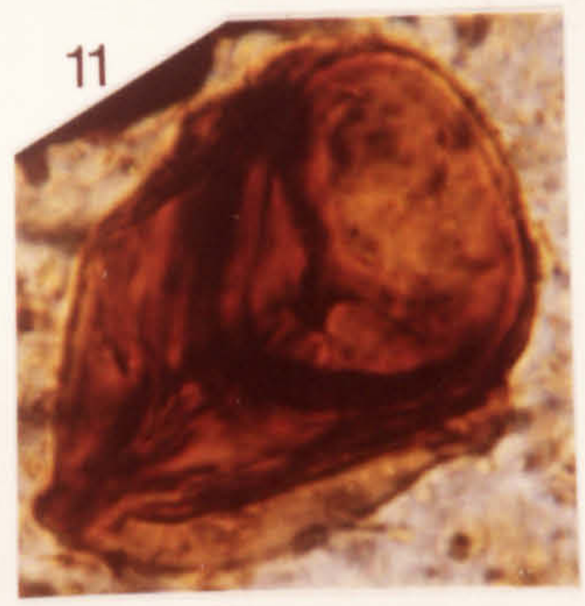


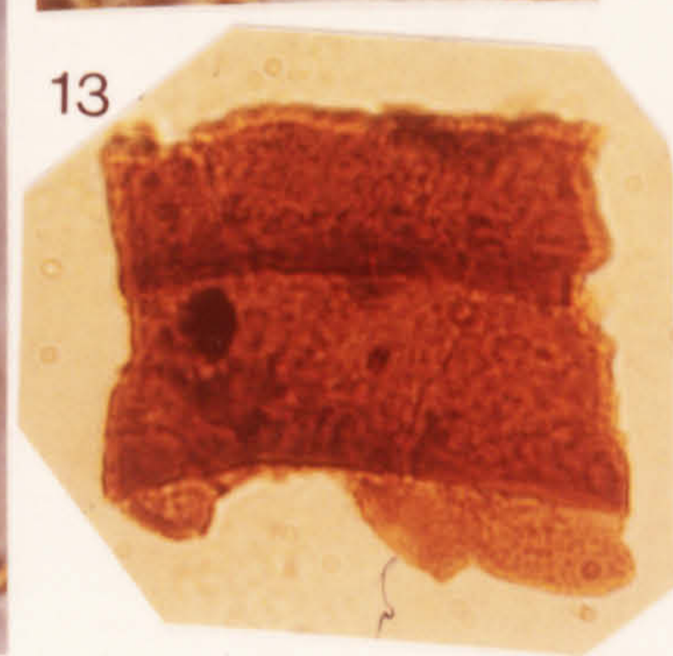


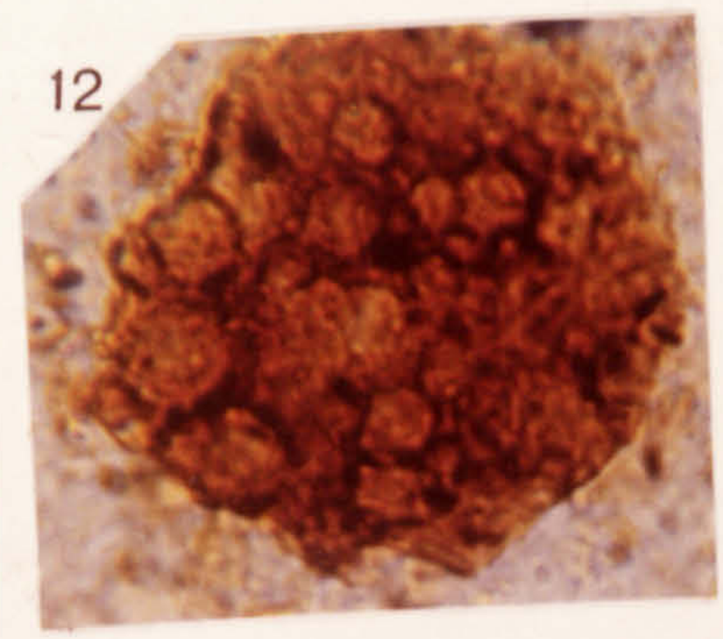












EXPLANATION OF PLATE 7

Note: All figures x 1000 unless indicated otherwise.

Leiosphaeridia laevigata Stockmans & Willière, 1963

Fig. 1 q_1PO27bL, Jabal Antar, Qusayba.

Navifusa sp.

Fig. 2 q_1PO27bF, loc. Jabal Antar, Qusayba.

Diexallophasis denticulata (Stockmans & Willière, 1963), Loeblich, 1970

Fig. 3 q_1PO27bL, loc. Jabal Antar, Qusayba.

Fig. 8 q_1PO27bc, loc. Jabal Antar, Qusayba.

Baltisphaeridium pilaris Cramer, 1964

Fig. 4 q_1PO27bK, loc. Jabal Antar, Qusayba.

Fig. 13 q_1PO27bC,loc. Jabal Antar, Qusayba.

Dictyotidium sp. B

Fig. 5 q_1PO27bG, loc. Jabal Antar, Qusayba.

Fig. 11 q_1PO27bG, loc. Jabal Antar, Qusayba.

Ooidium sp.

Fig. 6 q_1PO27bG, loc. Jabal Antar, Qusayba.

Baltisphaeridium cf. *nanum* (Deflandre, 1945) (Downie, 1959) Lister, 1970

Fig. 7 q_1PO27bA,loc. Jabal Antar, Qusayba.

Dictyotidium sp. A

Fig. 9 q_1PO27bG, loc. Jabal Antar, Qusayba.

Dictyotidium cf. dictyotum (Eisenack, 1938) 1955

Fig. 10 q_1PO27bC, loc. Jabal Antar, Qusayba.

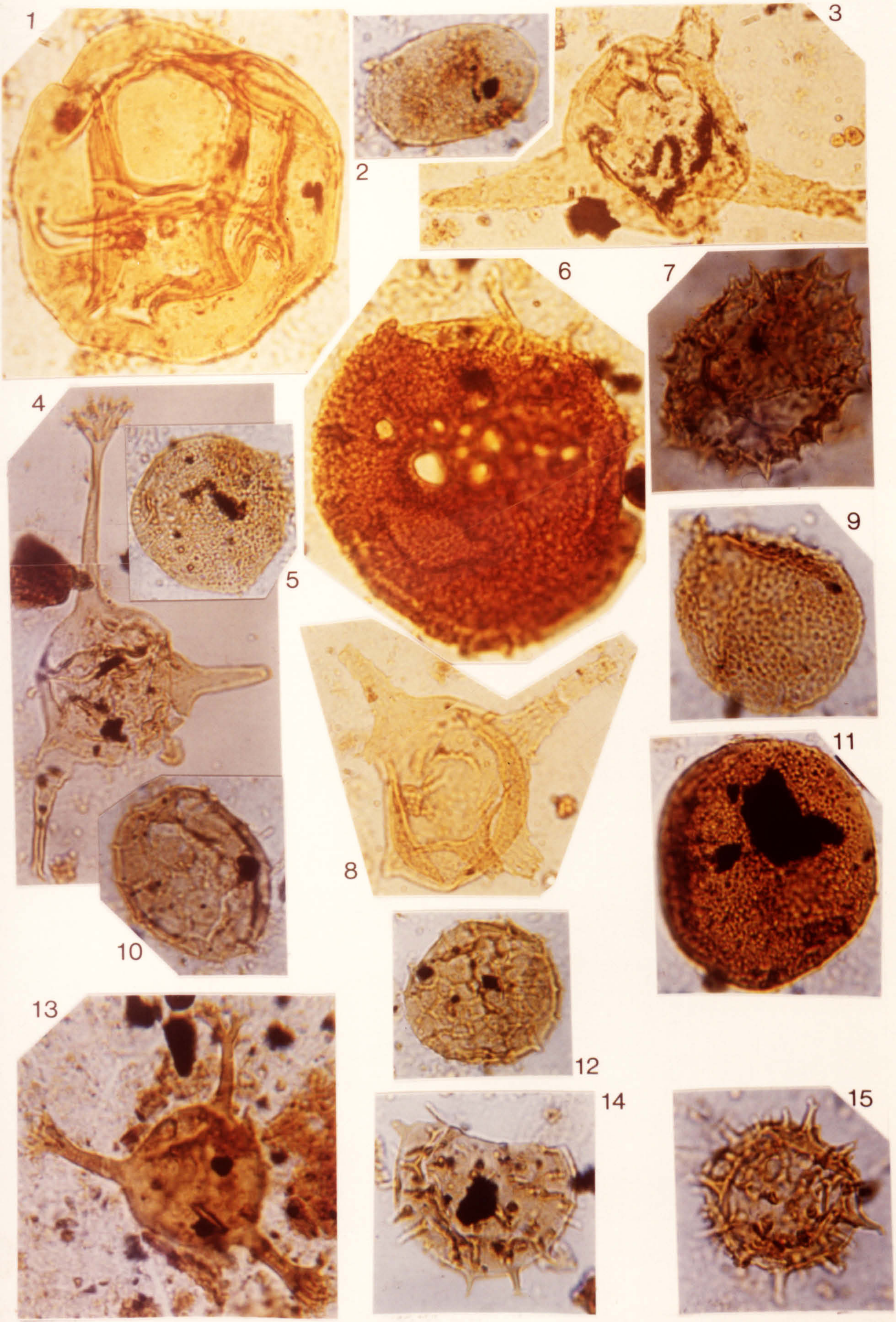
Fig. 12 q_1PO27bG, loc. Jabal Antar, Qusayba.

Ammonidium cf. cladum Downie, 1963

Fig. 14 q_1PO27bG, loc. Jabal Antar, Qusayba.

Fig. 15 q_1PO27bA, loc. Jabal Antar, Qusayba.

Plate 7



EXPLANATION OF PLATE 8

Note: All figures x 1000 unless indicated otherwise.

Leiosphaeridia laevigata Stockmans & Willière, 1963

Fig. 1 q_1PO27bG, loc. Jabal Antar, Qusayba, x 400.

Veryhachium sp.

Fig. 2 q_1PO27bF, loc. Jabal Antar, Qusayba.

Fig. 3 q_1PO27bA, loc. Jabal Antar, Qusayba.

Leiosphaeridia cf. microcystis (Eisenack) Downie, 1959

Fig. 4 q_1PO27bH, loc. Jabal Antar, Qusayba.

Veryhachium formosum Stockmans & Williere, 1960.

Fig. 5 q_1PO27bO,loc. Jabal Antar, Qusayba.

Fig. 8 q_1PO27bC, loc. Jabal Antar, Qusayba.

Buedingisphaeridium sp.

Fig. 6 q_1PO27bL, loc. Jabal Antar, Qusayba.

Baltisphaeridium cf. eoplanktonicum (Eisenack, 1955) Downie, 1959

Fig. 7 q_1PO27bCa, loc. Jabal Antar, Qusayba.

Fig. 10 q_1PO27bC, loc. Jabal Antar, Qusayba.

Veryhachium valiente Cramer, 1964

Fig. 9 q_1PO27bH,loc. Jabal Antar, Qusayba.

Fig. 11 q_1PO27bC, loc Jabal Antar, Qusayba.

Lophosphaeridium cf. granulosum (Staplin) Downie, 1963

Fig. 12 q_1PO27bC, loc. Jabal Antar, Qusayba.

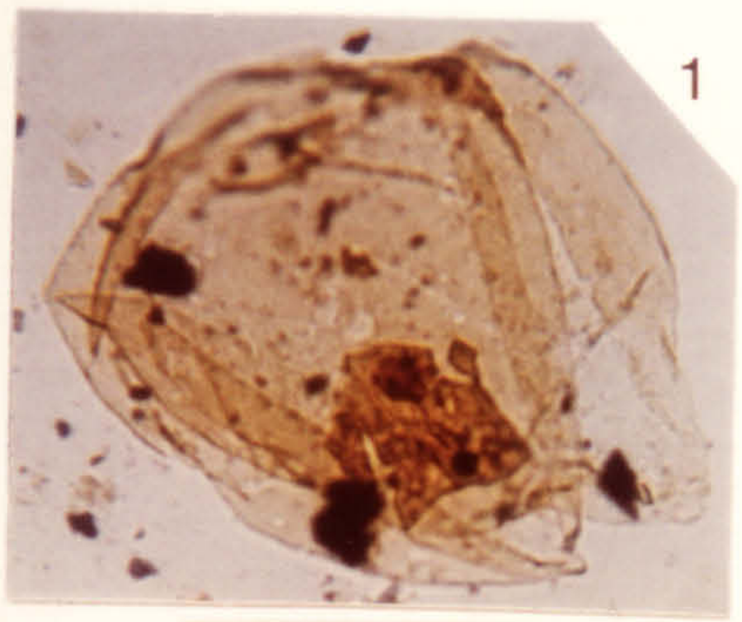
Fig. 13 q_1PO27bG, loc. Jabal Antar, Qusayba.

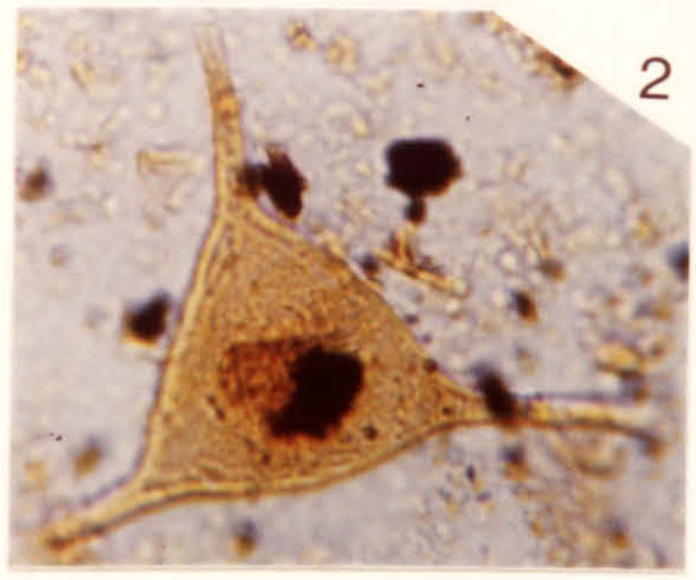
Fig. 14 q_1PO27bO, loc. Jabal Antar, Qusayba.

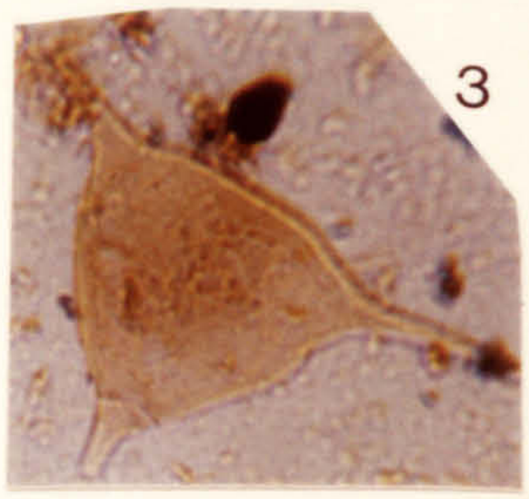
Visbysphaera cf. piriferum (Eisenack, 1954) Downie & Sarjeant 1963

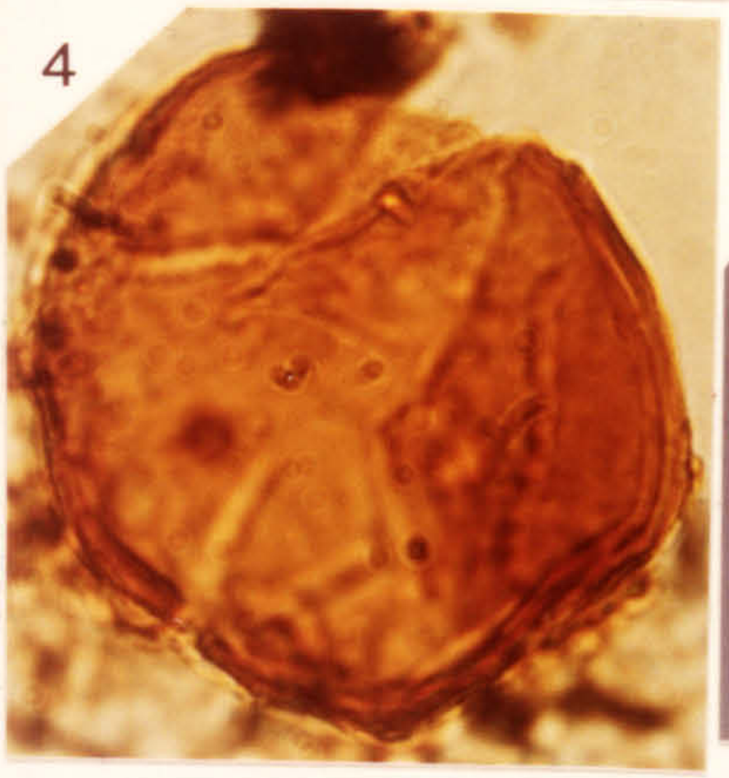
Fig. 15 q_1PO27bK, loc. Jabal Antar, Qusayba.

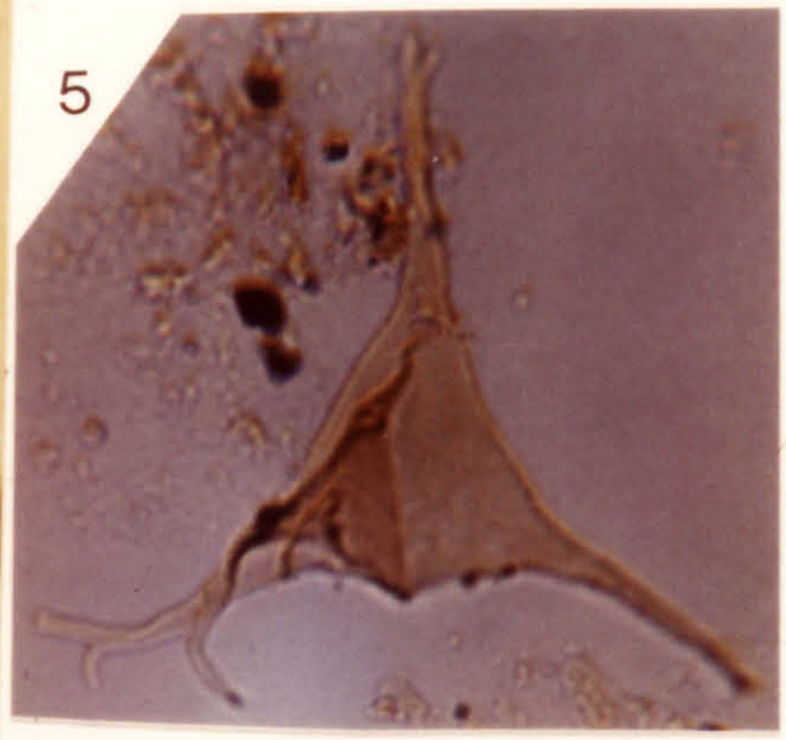
Plate 8

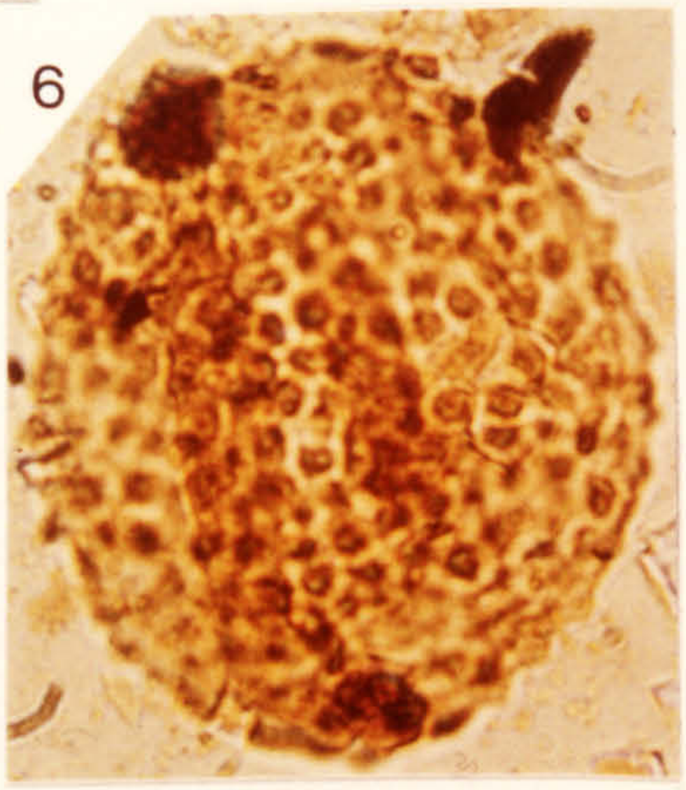


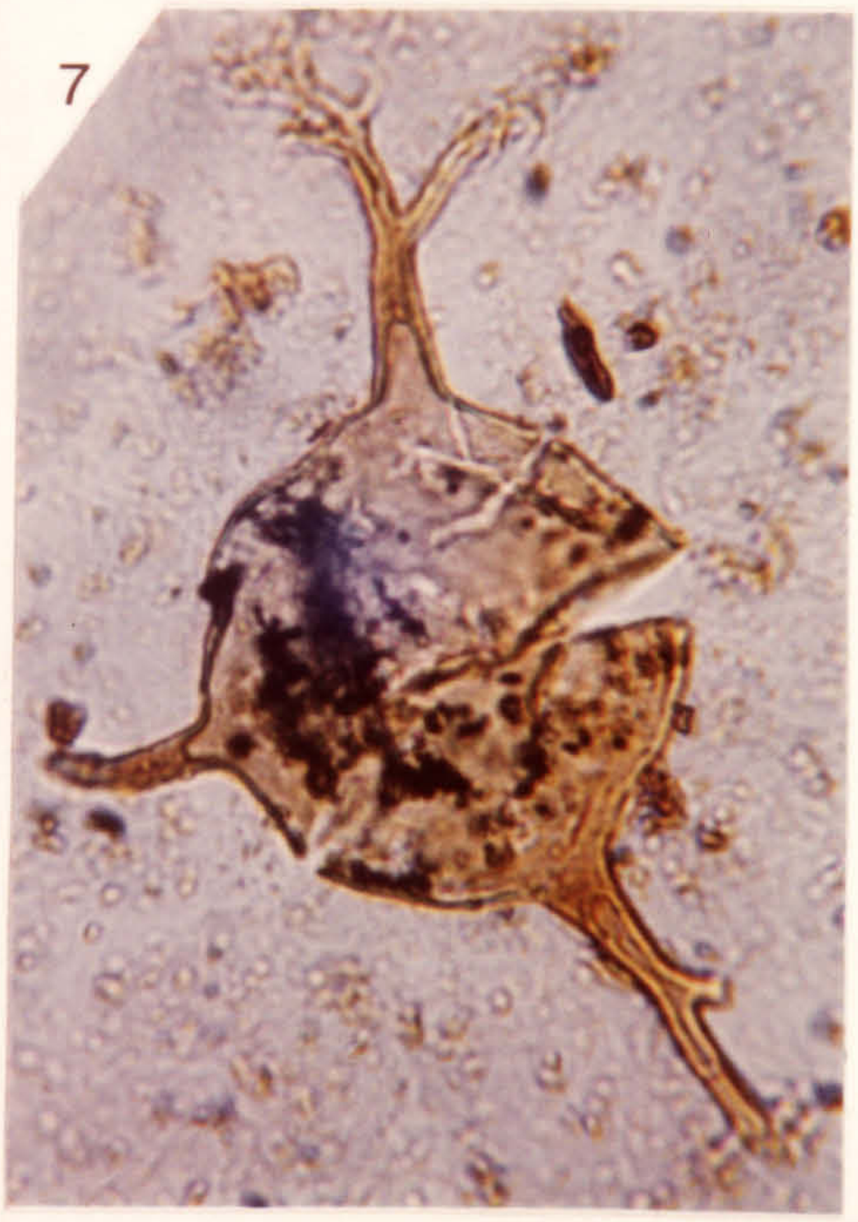


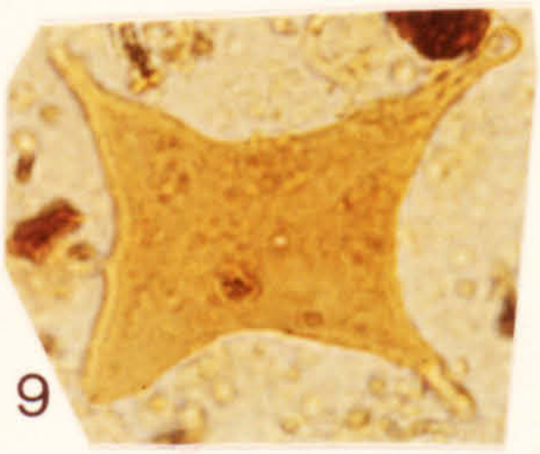


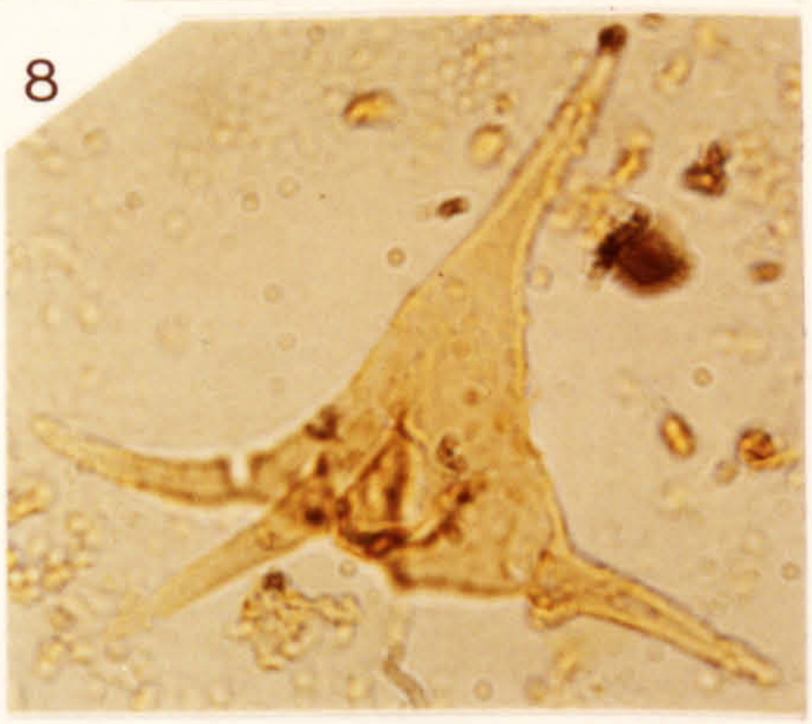


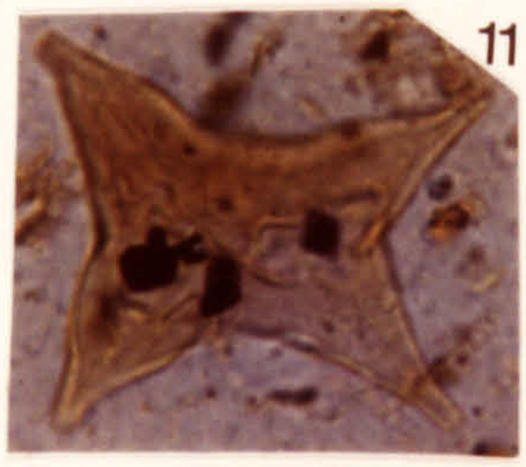


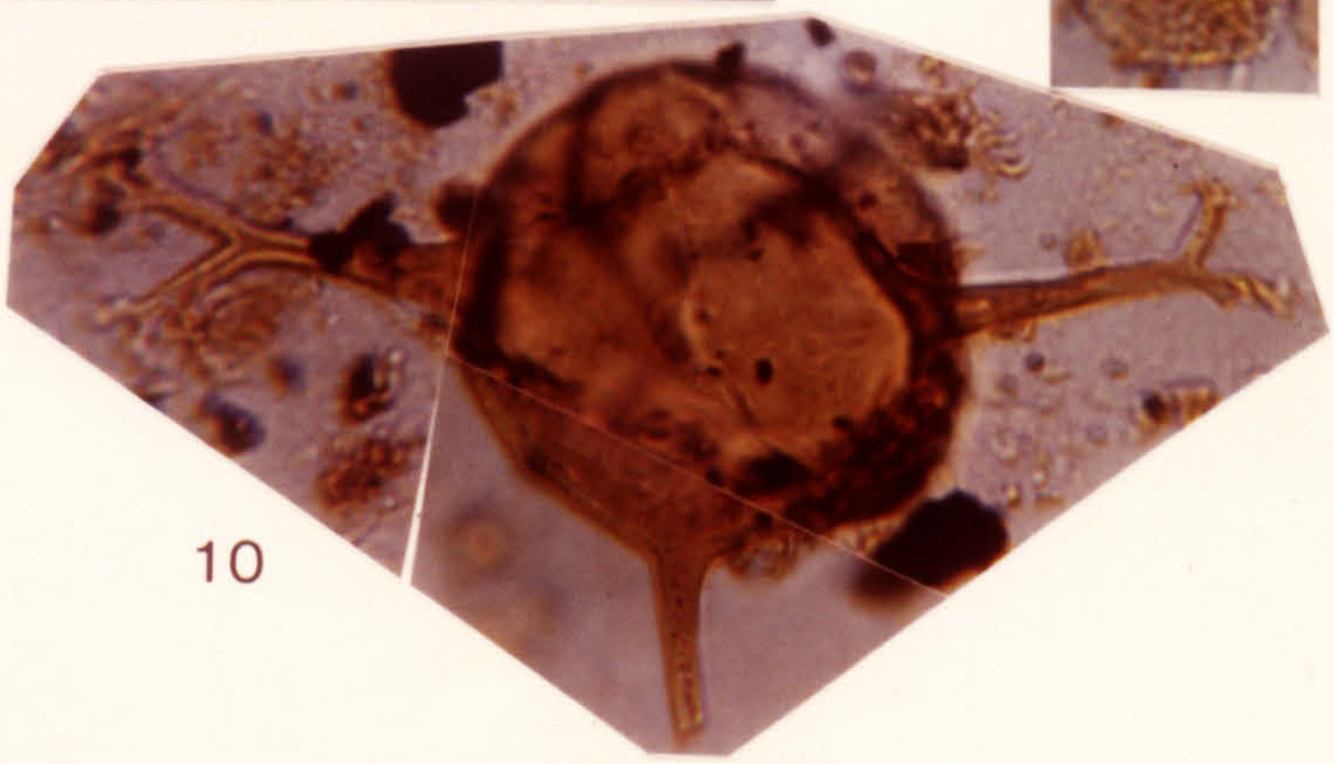


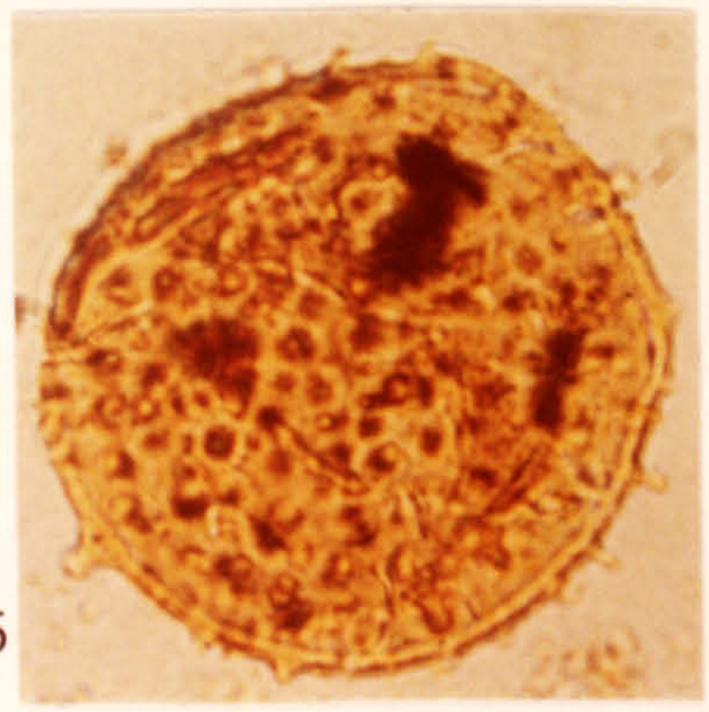












V

SIGNIFICANCE OF THE FOSSILS

a. Biostratigraphy

The main fossil groups from Al-Qassim district are treated here (trilobites, graptolites and palynomorphs) with these groups occurs a small number of brachiopods and bivalves. Fig. 12 lists the taxa of the main groups present and their age.

(i) Graptolites

The earliest graptolites from Al-Qassim indicate that the age of beds at Al-Bukayriah and Al-Khabra are equivalent to the Llanvirn Series, early Ordovician, with an association of Didymograptus bifidus (Hall). The graptolites at Al- Madbaa the age there is more likely equivalent to the Caradoc Series with the presence of only Glyptograptus (G.) incertus (Elles and Wood), and no association of any other graptolites. Moreover the lithological characters correspond closely to that unit of type section of the Tabuk Formation. The latest graptolites obtained from the Qusayba indicate that its age is Aeronian stage, Llandovery Series. They are the most common fossils. Correlation of the section at Qusayba with the type area of Llandovery shows the graptolitic beds almost equivalent to the Aeronian Stage, convolutus Zone; Cocks, Woodcock, Rickards, Temple and Lane (1984).

It yields Monograptus cf. decipiens decipiens Törnquist, Monograptus cf. convolutus (Hisinger), Monograptus cf. lobiferus M'Coy, Pristograptus regularis regularies (Törnquist) and some other graptolites similar to those Jones recorded (1949) (See Cocks et al., 1984).

(ii) Trilobites

Trilobite remains have been found in two localities of the study area. The scarcity of trilobites in these two localities and their absence from other localities, might be due to an inhospitable environment for trilobites. The earliest trilobites obtained from Al-Bukayria are three genera Hanchungolithus Neseuretus and Plaesiacomia; associated with Didymograptus bifidus (Hall). Hanchungolithus is a trilobite restricted to the Arenig and Llanvirn Series, and here is found in the Llanvirn together with the other two genera. The latest trilobites are Platycoryphe and Calymene both found in Qusayba and associated with Llandoverian graptolites.

(iii) Microfossils

Acritarchs and spores are found at one level in Qusayba, they are absent from other sections. The acritarch assemblage indicate most probably the Aeronian Stage as does their association with graptolites of this stage, but it is difficult to determine their biozone. Such acritarchs found are Ammonidium cf. cladum Downie, Dictyoitidium cf. dictyotum (Eisenack), Diexallophasis denticulata (Stockmans and Willière) and Leiosphaeridia laevigata Stockmans and Willière.

Graptolites, trilobites and palynomorphs	Series		
	Llanvirn	Caradoc	Llandovery
	Localities		
	Al-Bukayria	Al-Madbaa	Qusayba
Didymograptus bifidus (Hall)	•		
Glyptograptus (G.) incertus (Elles & Wood)		•	
Climacograptus cf. normalis Lapworth			•
Monograptus cf. convolutus (Hisinger)			•
Monograptus cf. decipiens decipiens Törnquist			•
Monograptus cf. lobiferus (McCoy)			•
Monograptus sp.			•
Pristiograptus regularis regularis (Törnquist)			•
Pristiograptus cf. nudus (Lapworth)			•
Lagarograptus tenuis (Portlock)			•
Petalograptus ovatoelongatus (Kurck)			•
Petalograptus minor Elles			•
Hanchungolithus cf. primitivus (Born)	•		
Neseuretus tristani (Desmarest)	•		
Plaesiacomia cf. vacuvertis Thomas	•		
Platycoryphe cf. dyaulax Thomas			•
Calymene sp.			•
cf. Ambitisporites avitus Hoffmeister			•
Nodospora burnhamensis Strother & Traverser			•
Tetrahedraletes medinesis Strother & Traverse			•
Tasmanites cf. medius (Eisenack)			•
Ammonidium cf. cladum Downie			•
Baltisphaeridium cf. eoplanktonicum Eisenack			•
Baltisphaeridium cf. nanum (Deflandre)			•
Baltisphaeridium pilaris Cramer			•
Buedingisphaeridium sp.			•
Diexallophasis denticulata (Stockmans& Williere)			•
Visbysphaera cf. piriferum(Eisenack)			•
Dictyotidium cf dictyotum (Eisenack)			•
Dictyotidium sp. A.			•
Dictyotidium sp. B.			•
Leiosphaeridia laevigata Stockmans & Williere			•
Leiosphaeridia cf. microcystis (Eisenack)			•
Lophosphaeridium cf. granulosum (Staplin)			•
Navifusa sp.			•
Veryhachium formosum Stockmans & Williere			•
Veryhachium valiente Cramer			•
Veryhachium sp.			•
Ooidium sp.			•

Fig. 12. Fossil records tied to localities and age.
The black dots indicate species found in that locality.

b. Palaeobiogeography

1. The early Ordovician migration of Neseuretus and Hanchungolithus in the Tethyan region.

The distribution and evolution of the trilobite faunas is an important factor in the reconstruction of the palaeogeographic map of the world in early Ordovician, and must indicate something about the routes of trilobite migration. Some of the characteristic Tethyan faunas in early Ordovician time are those containing the genera Neseuretus and Hanchungolithus. These genera are part of calymenid-trinculied province (Whittington, 1966) which at present cover generally the Mediterranean and Bohemia; they come under the broad heading of the shelly faunas of Bohemia (Dean, 1967). They are inroled also within the Selenopeltis province (Whittington and Hughes, 1972). The Tethys represented an ancestral Mediterranean as far as Cambrian faunas were concerned (Richter , 1941). Geographically the Ordovician Tethys may have occupied the present site of the Mediterranean, together with the north-western portion of Africa and much of southern and south central Europe (Dean, 1967). The lithologies of strata which have yielded Hanchungolithus and Neseuretus from Saudi Arabia are similar to those of the Mediterranean portion of the Tethys. The calymenacid and trinucleid genera e.g. Neseuretus, Plaesiacomia and Hanchungolithus are regarded as characteristic and an important constituent of the Tethyan faunas (Dean, 1967). These three genera have been found at different localities in Saudi Arabia, as in Thomas (1977), Fortey and Morris (1982) and the present study.

Concerning the migration of Hanchungolithus and

Neseuretus, Dean (1967) has discussed this subject relative to the trilobite faunas as a whole. Here it will be confined to the last two genera and their appearance in Saudi Arabia. The appearance of Myttonia in the Anglo-Welsh area in Arenig time probably gave rise to other genera in the Anglo-Welsh area and, by evolving a more orderly arrangement of pits frontally, can provide a suitable ancestral base for Hanchungolithus (Dean, 1967). The presence of H. primitivus (Born) in the Extensus zone and Neseuretus from the Arenig in France; in Britain Neseuretus has been found from the Shelve district of Arenig succession and even from earliest strata but the absence of the fauna in Bohemia suggest evolution and migration of the faunas from the Anglo-Welsh area in Arenig time as far as France, (Dean, 1967). The occurrence of Neseuretus in France in Arenig time and also in Iberia in the Llanvirn and later (Desmarest, 1817, and Hammann, 1977) may suggest that faunas migrated from France in Arenig time towards Iberia and might be accompanied by Hanchungolithus.

In north Africa Neseuretus is known from Morocco from early Arenig and later rocks (Destombes, 1967). Whiteman (1971) recorded Neseuretus in Arenig beds from Algeria as Synhomalonotus tristani. In Tunisia Neseuretus is found in Llanvirn or Llandeilo time (Whiteman, 1971). There is a similarity in facies between Algeria and Europe in the early Ordovician (Legrand, 1974). The same facies of Algeria continues eastwards into Libya but with the absence of Neseuretus (Fortey and Morris, 1982). This evidence may indicate Neseuretus migration between Iberia and north Africa. Dean (1967) has demonstrated this in his map of Llanvirn faunas.

In China Neseuretus and Hanchungolithus are found in Llanvirn rocks (Lu, 1975 and 1963). The Ordovician faunas there have relations with the European fauna and are different from that of north China (Wang, 1980). The occurrence of the trilobite genera in Saudi Arabia in Llanvirn, Neseuretus (Fortey and Morris, 1982), Plaesiacomia (Thomas, 1977) and Neseuretus plaesiacomia and Hanchungolithus gives more evidence that Neseuretus and Hanchungolithus were on the route of migration from the western part of the Tethyes region towards the east (China) (Dean, 1967; Fortey and Morris, 1982). See Figure 13.

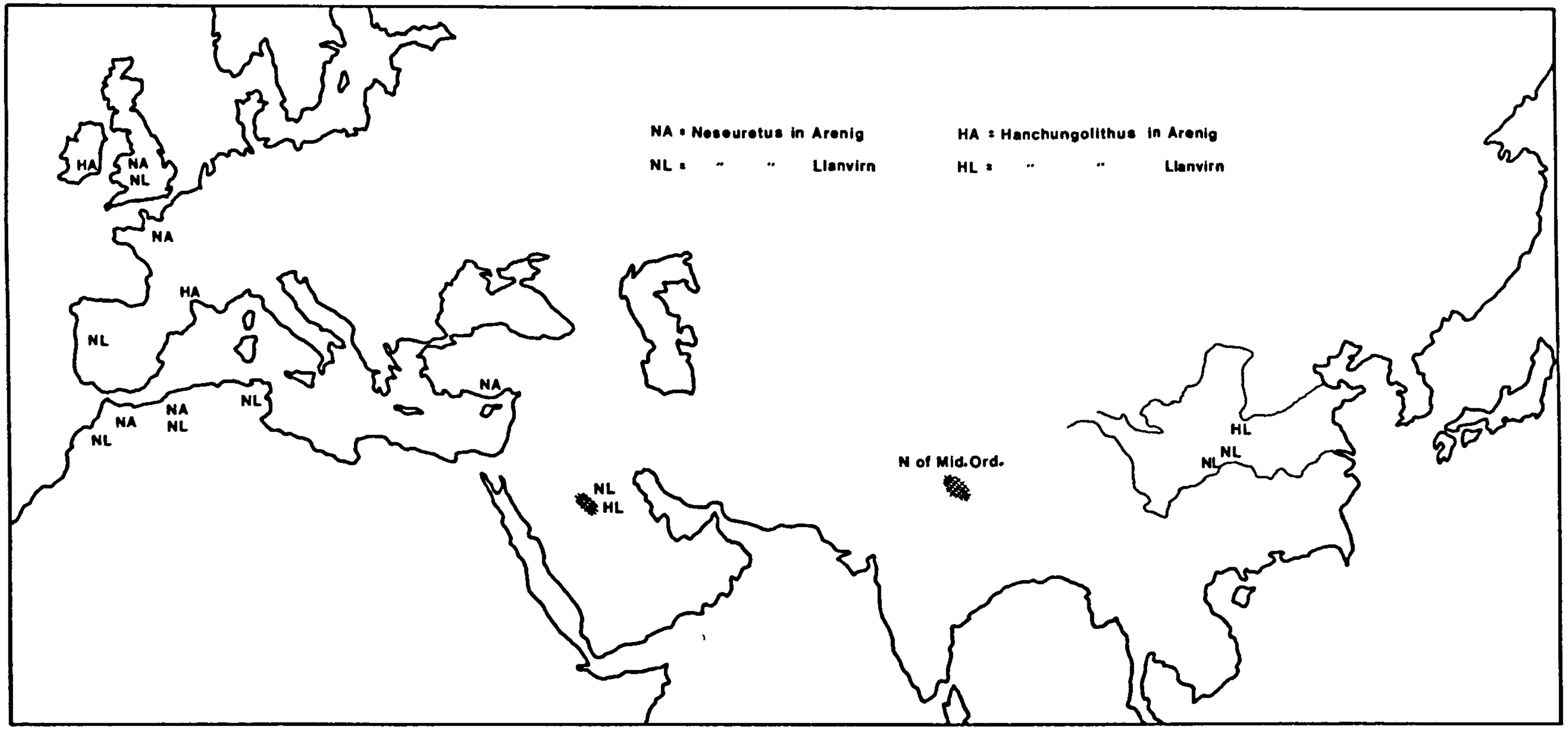


FIG. 13 DISTRIBUTION OF TRILOBITES NESEURETUS AND HANCHUNGOLITHUS IN EARLY ORDOVICIAN TIMES

2. Cold-water fauna.

North African glacial deposits have been described by several authors (Tücker and Reid, 1973) and similar (carbonate-free) deposits have been found in the upper Ordovician (McClure, 1978) of the central part of Saudi Arabia (Al-Qassim). The presence of an ice sheet in Caradoc time at the Khashm ar Ran and at Jalas Saiyah, which is equivalent to Al-Madbaa section of the present study a distance of 100-120 km north west of Al-Madbaa has been established. This glacial evidence implies that the cold climate generally dominated the region in the Ordovician and early Silurian, and had strong influence on the biology and sedimentation in the local environments.(See also Spjeldnaes, 1976).

In consequence the marine faunas of this region were adapted to cold conditions, but much of the succession has no fauna content at all. In these circumstances the faunas may be expected to show a low diversity of taxa, and perhaps to contain an abundance of individuals. It has been found in the study area that such a low diversity of fauna occurred. Trilobites such as Neseuretus and Plaesiacomia associated with a few brachiopods and bivalves in early Ordovician are typically a cold water fauna. Fortey and Morris (1982) regarded the Neseuretus fauna as an indicator of epicontinental seas at high latitudes.

In early Silurian time the low diversity fauna also occurred in the present region, and this gives an indication that the region remained at a high latitude. Moreover an achritarch assemblage substantiates this idea as it contains no Deunffia and Domasia of low latitudes facies and has Veryhachium valiente and its allies of high latitudes (Cramer, 1970) (Cramer & Diez, 1972).

3. Hanchungolithus cf. primitivus; its significance

If the Hanchungolithus cf. primitivus from Al-Bukayriah described above is correctly assigned, it is of particular interest not only as the first record of this genus and the fourth trilobite to be known from Saudi Arabia, but also it can be used as a guide fossil. Moreover, in the evolution of the Trinucleidae, the Hanchungolithinae represent the wide spread of the ancestral trinucleid group (Hughes, Ingham and Addison, 1975). Also the recapitulation in the Trinucleidae can be shown between Hanchungolithinae mature genera and later meraspid features genera of Reedolithus and Tretaspis (Lu, 1963, 1964) (Hughes, Ingham and Addison, 1975). See figure 14.

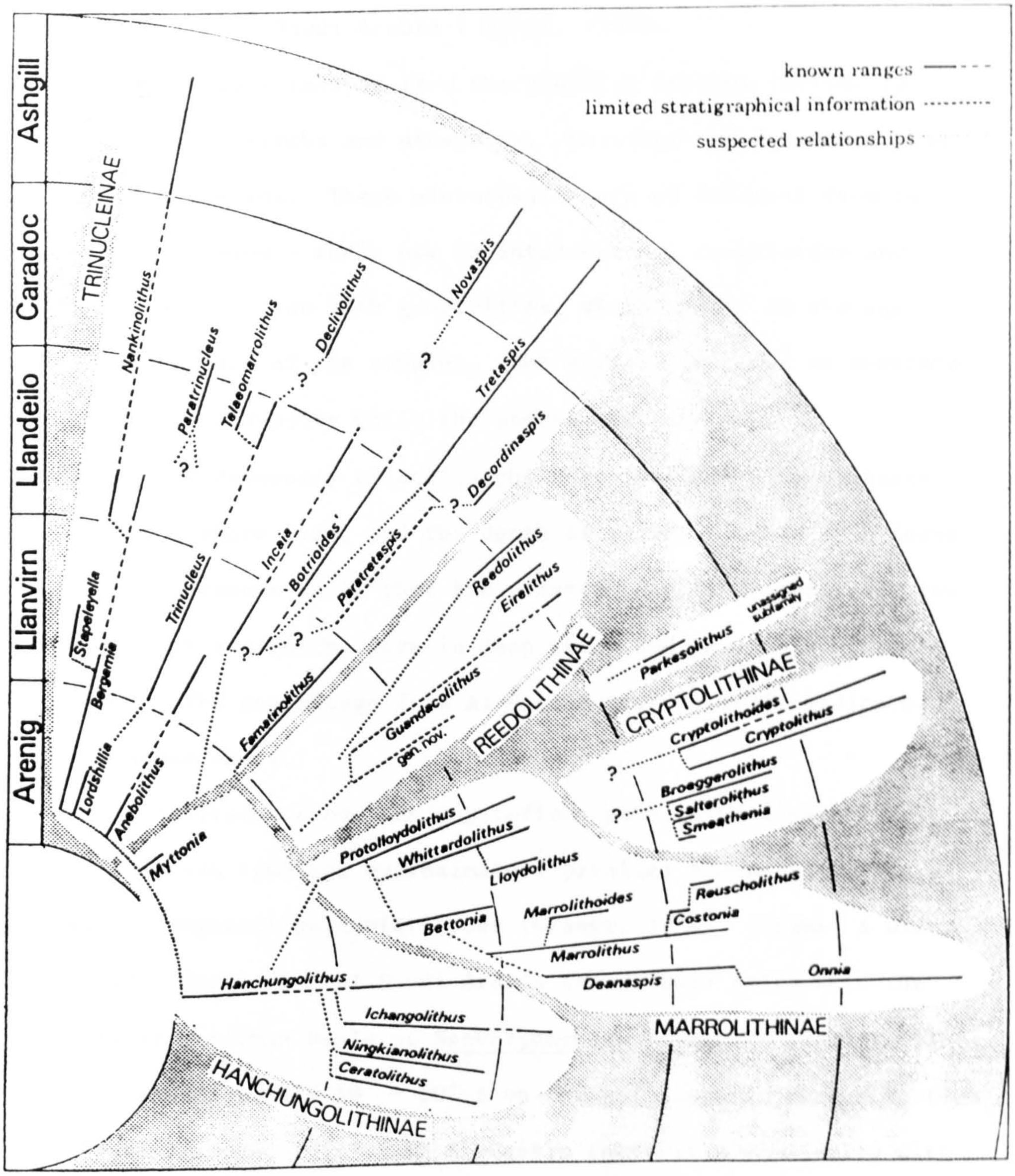


FIG. 14 SUGGESTED EVOLUTIONARY RELATIONSHIPS WITHIN THE TRINUCLEIDAE (from Hughes, Ingham, Addison, 1975)

4. Palynomorphs

Silurian palynomorphs were first observed from the subsurface of Saudi Arabia (Hemer, 1968).

The palynomorphs from the yielding stratum include two kinds - acritarchs and miospores. Chitinozoans and scolecodonts are not present. These microfossils are of interest from two points of view - their use in interregional correlation and their association with graptolites, which assist in the age determination of the samples. The acritarchs occur in moderate numbers and density while the spores are rare.

The diversity of acritarchs were influenced by distance from the shore line, and the depth of water. It has been found on the offshore shelf that the greatest diversity occurred, low diversity acritarchs were in deep water and near shore (Dorning, 1981). The assemblage from Al-Qassim most probably indicates off shore shelf.

Acritarch provinces may reflect paleoclimatological belts in Silurian time and approximately parallel biofacies boundary with a magnetic palaeolatitudes (Cramer, 1970) (Cramer & Diez, 1972). North central Saudi Arabia (Al-Qassim) falls into the Brasilian-Libyan Realm of Neoveryhachium carminae - facies. This lies approximately 50° - 60° S on the palinspastic reconstruction (Cramer & Diez, 1972). In Al Qassim there is a similarity with the Veryhachium valiente - subfacies of the Neoveryhachium carminae - facies.

CONCLUSIONS

Conclusions:

This study dealt with exposures of strata in the Al-Qassim area thought to be of the Tabuk Formation and which have been examined for fossils. For the most part these rocks are barren and monotonous sandstones and shales. From a small number of localities fossils have been found. They reveal two kinds of fossils macrofauna and palynoflora, the principal kinds being given below. From Al-Bukayriah a trilobite fauna is described. From Qusayba graptolites and palynomorphs have been recorded. These indicate Ordovician and Silurian ages, not Devonian, the date tentatively given previously to these strata. The fossils occur in assemblages of very small numbers of taxa but large numbers of individuals. This is consistent with preservation of cold-water floras and fauna in non-carbonate sediments. Carbonate facies fossils are totally lacking. The sedimentology of the enclosing rocks also is in accord with the hypothesis that the Ordovician and Silurian sediments in this region were deposited in cold and shallow marine waters. The correlation of the local sections to the Tabuk type sections may be made to only a limited extent, and further work on the biostratigraphy at Tabuk and at Al-Qassim is needed.

The macrofossils, however, do show affinities to those of the same ages in China and the mediterranean (Tethyan) region of Europe. In those regions the species associated with the forms common in Al-Qassim are more numerous and different and possibly represent communities of warmer-water environments.

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